RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXVIII.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1895. **[February.**

Annual Report of the Geological Survey of India and of the Geological Museum, Calcutta, for the year 1894.

Staff of the Survey.

Dr. William King retired from the Directorship on the 16th July last, after a total length of service of 37 years, seven of which were passed as Director. His services are briefly noticed in the Records, Vol. XXVII, page. 109.

Mr. T. W. H. Hughes was compelled to retire from the 17th October, owing to an unfortunate accident, which has deprived him of his eyesight.

Mr. W. B. D. Edwards, having obtained an appointment as Inspector of Schools in England, has resigned his appointment from the 4th November 1894.

The vacancies thus created will be filled in due course by men selected by Her Majesty's Secretary of State.

Mr. William Anderson was appointed by the Secretary of State to be Mining Specialist on the Survey, and joined the Department on the 15th November 1894.

At the beginning of the year 1894, the officers of the department not on leave were disposed as follows :—

Myself with Mr. F. H. Smith and Lala Kishen Singh in Baluchistán; Mr. T. H. D. La Touche in charge of boring at Sukkur; Mr. P. N. Bose, Rewah; Mr. C. S. Middlemiss, Madras; Dr. H. Warth, Madras; Mr. P. N. Datta, Central Provinces; Mr. T. H. Holland and Dr. F. Noetling at Head-Quarters.

At the beginning of the present field-season the officers of the department were distributed as follows :—

Mr. R. D. Oldham and „ Datta	Rewah.
Mr. LaTouche and Lala Hira Lal	Sukkur.
Mr. P. N. Bose .	. Central Provinces.
„ Middlemiss .	. Madras.
„ Holland .	. Head-Quarters.
„ Smith .	. Baluchistán.
Dr. Noetling .	. Upper Burma.
Mr. Anderson .	. Chota Nagpore.

Summary of work accomplished.

In the following notes will be found an outline of the work done during 1894.

During the season of 1893 to 1894 Mr. Bose surveyed a rather extensive area in Rewah and the ground east of it, in all more than 2,000 square miles, of which, however, some parts had already been reported on by Mr. Smith and Kishen Singh, who were attached to the party under Mr. Hughes in 1893. Mr. Bose distinguishes the following formations in descending order:—

Rewah.
P. N. Bose.
R. D. Oldham.
P. N. Datta.

4. Gondwanas.
3. Vindhyans.
2. Transitions.
1. Metamorphics.

and amongst the intrusive rocks: granite and diorite.

He separates a schistose formation from the transitions proper, *i. e.* the representatives of the Bijáwar system, and includes a belt of gneissose rocks amongst the former, being probably the result of local metamorphism of the schistose series by the intrusive granites. The lower vindhyans rest unconformably on the transitions.

Mr. Oldham has taken over charge of the Rewah survey this field-season, with Mr. Datta to assist him; he has since had an opportunity of inspecting Mr. Bose's work, and has come to the conclusion that the so called "gneiss" of Mr. Bose is in reality an intrusive granite. Mr. Oldham has not yet been able to confirm the separation of the schistose beds from the transitions. If the "gneiss" is only intrusive granite, it seems very probable that the difference in lithological character between the schistose and transition series is due to contact metamorphism. Mr. Bose describes the two series of rocks as conformable and renders their position in this manner in his section.

I myself crossed this belt of transition rocks further eastwards some years ago and was struck at that time with the general resemblance of the series with the great thickness of beds which underlie the lower silurian of the Himálayas, which I had comprised under the name of the haimantas and of which the upper portion may possibly he correlated with the cambrians. I still believe that this series of transitions underlying the lower vindhyans will turn out to be an equivalent of the haimanta group of the Himálayas.

Mr. Datta is working at the lower vindhyans north of the Sone and has been able to examine some sections in greater detail, but so far Mr. Oldham suspects that the lower vindhyans (so-called) belong to a different and unconformable series to the vindhyans proper in which opinion he differs from Mr. Mallet, (See Vol. VII of the Memoirs.)

Mr. Datta had been posted to the Bhandara District during the previous field-season, and he was engaged at the beginning of 1894 on the geological survey of part of a still unknown ground in the Central Provinces. He managed to go over two separate areas, namely, part of the valley of the Kanhun river in Nagpur and Chindwara, and secondly, parts of the Bhandara district. In the first-named district he came across a crystalline and schistose series with intrusions and spreads of igneous rock, which is unconformably overlaid by lameta beds; the latter proved unfossiliferous.

Central Provinces.
P. N. Datta, 1893-94.
P. N. Bose, 1894.

In the second or Bhandara area Mr. Datta observed crystalline rocks with transition beds, the series forming the western extension of the Chattisgarh basin. A number of sections were examined in detail, but until the rock-specimens can be examined microscopically, not many new facts can be made out regarding the structure of that part of India. Mr. Datta has brought back a fine collection of hand-specimens for the museum.

At the beginning of last field-season Mr. Bose was posted to the same ground, and he started work in continuation of the surveys of Dr. King in the Chattisgarh division. He believes to have met with confirmatory evidence in favour of the unconformable superposition of certain beds over the Chilpi Ghât series, which may possibly represent lower vindhyans in this area. It is a point, however, which will require much clearer evidence before this view can be finally adopted. It is directly opposed to both Mr. Medlicott's and Dr. King's views (for the latter see Records, Vol. XVIII, p. 190).

Madras.
Mr. C. S. Middlemiss.
Dr. H. Warth.

During December 1893, Mr. Middlemiss was transferred to the Madras Presidency, where he began a detailed investigation of the mineral resources and petrology of the Salem district, with special reference to the occurrence of corundum.

During the first few months of 1894, a cursory examination of the ground was only made, but nevertheless some very valuable observations were the result; he came to the conclusion that the corundum is not an original mineral constituent of the gneissose rocks in which it occurs, but is the result of a mineral change or metamorphism of the matrix rock. He infers this from the patchy way in which it occurs, from the zone, or shell of carbonate of lime and of quartz (at Sithampundi), and from the similar shell of pink felspar enclosing the corundum crystals in the Paparapatti rock. The general aspect is, as if it had segregated out in certain places, leaving an enclosing lenticular patch of altered gneiss and an envelope of another mineral behind. This field-season Mr. Middlemiss is provided with the necessary outfit for a microscopic examination of the rocks, and we may expect a large addition to a more exact knowledge of the petrology of Madras, which, it is to be hoped, will eventually form a useful and more or less complete guide to the crystalline rocks of India. He divides the Salem rocks provisionally as follows:—

Crystalline gneissic rocks—

(1) White and grey quartzo-felspathic	rocks.
(2) Purple and grey biotite gneissic	do.
(3) Hornblende gneissic	do.
(4) Hypersthene gneissic	do.

The above, though mutually interbanded in places, also predominate individually over certain areas. Hence they may be separated when traversing from East to West:—

(*a*) The Morappur	band of	hornblende	gneissic	rocks.
(*b*) The Mukhunur	"	hypersthene	"	"
(*c*) The Dharmapuri	"	quartzo-felspathic	"	"
(*d*) The Paparapatti	"	biotite with corundum.	"	"

Foliation of the above varieties seems to be genuine, consisting of (1) layers of different width, often contorted, composed of different minerals, and combinations of minerals, (2) layers of different degrees of coarseness of grain. The rocks are not as a rule fissile to any extent along the foliation.

Intrusive rocks—

(A). Purple granites are non-foliated massive rocks, occurring sparsely and are intruded along foliation of gneissic rocks. They often include large pieces of hornblendic rocks.

(B). Dark traps, doleritic, composition augite and plagioclase, non-foliated, tough, massive dyke rocks, crossing the foliation of the gneissic rocks at right angles; fairly numerous, but difficult to trace far, except locally.

The cretaceous rocks of Pondicherry; Dr. H. Warth.

It was desirable to study the cretaceous beds of Pondicherry in greater detail, and collect therefrom good material for description; Dr. Warth was deputed to do so, and he devoted the field-season of 1893-94 to this task.

The fossils which were collected by Dr. Warth are somewhat dissappointing, both as regards numbers and preservation, but they have been sent to Dr. Kossmat of the Vienna University, who is also engaged on the determination of the collection of cretaceous fossils from Trichinopoly belonging to the Madras Museum. From a preliminary note which this gentleman has sent it appears that the entire series of Pondicherry beds belongs to the Ariyalur group of Southern India.

Himálayas. Mr. T. H. Holland.

It will be remembered that a landslip occurred early in September 1893 and dammed up the Birahi Ganga which drained 90 square miles above Gohna. The locality was examined by Mr. Holland early in March 1894, when the lake was nearly 3 miles long with a maximum width of 1 mile. Mr. Holland's report described (1) the geographical and geological features of the Birahi Ganga valley, (2) a description of the landslip and lake, and (3) a discussion of the causes which led to the landslip.

With regard to the second point he predicted—

(1) That the lake would be full and would overflow the barrier about the middle of August.

(2) That the dam was strong enough to resist the pressure of the water before overflow.

(3) That after overflow the lake would be reduced to one about 3½ miles long, and that this would remain permanent for some time.

(4) That landslips would occur into the lake.

The lake overflowed the dam early on the morning of August 25th, the stream flowing down the steep slope to the bed below Gohna. The erosion thus continued until late at night, when a channel having been cut back to the lip of the lake rapid recession of levels followed until the erosion was checked by reduction of the slope and exposure of large blocks of dolomite, by removal of the fine detritus forming the upper part of the dam. The lake left is about 3 miles long and over 300 feet deep, with, according to the latest accounts, every chance of being historically permanent, although its gradual destruction by silting up of the basin and gradual erosion of the dam will, geologically considered, happen at no distant time. The landslips which have occurred into the lake have with the silt raised the bottom nearly 100 feet. The dam is now quite firm and the outlet through the gorge cut in its upper part is over a rocky bed with a slope of about 1 in 15.

In this gorge, cut through a portion of the first of the two main falls, there are exposed, according to Lieutenant Crookshank, R.E., great bundles of strata dipping towards the south at an angle of about 50°, which he regards as a striking confirmation of Mr. Holland's conclusion with regard to the peculiar character of the first slip in which Mr. Holland considered that the hill must have pitched forward and not have slipped down in stream-fashion after the manner of smaller and more common landslips. (Records, Vol. XXVII, page 59.)

Punjáb.
Dr. F. Noetling.

The alarming increase of accidents in the Dandote coal-mines made an immediate inspection of the Dandote (Punjáb) and Warora (Central Provinces) collieries desirable; the Inspector of Mines in India had not been appointed then (October 1893), and Dr. Noetling was therefore deputed on this duty. In addition to this inspection, Dr. Noetling was able to add to our knowledge of the older palæozoic strata of the Salt-Range. He has since published his observations in a paper in the Records, Vol. XXVII, pages 71 to 86, which clears up many discrepancies in the Salt-Range geology.

Mr. Wynne, who described the geology of that range in greater detail, was the first observer who insisted on the age of certain beds as older than carboniferous and to be quite distinct from the latter. On the strength of Dr. Waagen's determination of the few fossils which had then been found, these beds were considered to be of silurian age. Later on Dr. Waagen combated this view and claimed a lower carboniferous age for these beds, but modified this opinion as cambrian trilobites were found, whilst his work, Vol. IV of Ser. XIII of the Palæontologia Indica, was in progress.

Dr. Noetling, who had studied the Khusak section carefully (already well described by Mr. Middlemiss, Records XXXIV, page 24) now divides the cambrian system of the Salt-Range as follows, in descending order:—

4. Bhaganwalla group, or salt-crystal pseudomorph zone.
3. Jutana group, or Magnesian sandstone.
2. Khussak group, or Neobolus beds.
1. Khewra group, or Purple sandstone.

Each of which divisions he further sub-divides.

The fossils which he has found, have been forwarded to Dr. Waagen for determination.

Sukkur boring.
Mr. T. D. La Touche.
Lala Hira Lal.

The boring for petroleum which has been put down at Sukkur on the Indus has steadily progressed, and it has been sunk to a depth of 957 feet. Considerable difficulty is occasionally experienced, but not more than might have been anticipated. The practical result is so far *nil*, although signs of escape of gas have been observed at depths below 800 feet, which afford some slight hope of obtaining oil further down. But the boring is not without some geological interest, as it proves that the thickness of the strata is much in accordance with the estimate which I have given, which was practically taken from the Sharigh section. The lithological character of the beds passed through is very similar to that of the Sharigh section, and in some respects, particularly in the upper portion, very like the section near Khattan. As near Sharigh, so also at Sukkur, a great thickness of clays, alternating with thin limestone bands, and traversed by numerous gypsum veins and nests, occurs below the light coloured upper nummulitic limestone of Sukkur.

The boring ought to reach the carbonaceous horizon within the next 200 to 250 feet, if the section corresponds as closely with the Sharigh section, as seems likely.

Mr. La Touche reported in December 1894 that he had examined a spot about 8 miles south of Rohri, where the freshly broken soil emits a strong smell of petroleum, which may indicate the escape of oil below the thickness of alluvium. There is no rock *in situ* within miles of the spot, but the question is being investigated now.

Baluchistán.
C. L. Griesbach.
W. B. D. Edwards.
F. H. Smith.
Lala Kishen Sing.

Considerable progress has been made in the geological survey of Baluchistán, which is, perhaps, one of the most interesting countries in the world, from a structural point of view.

Mr. Edwards joined my party in the early part of the year and was told off to examine the so-called Quetta coal-area. Before he could quite finish the task, he became seriously ill, which led eventually to his retirement this year.

Mr. Smith joined my party in the autumn of 1893, and after continuing the work which Mr. Edwards had begun, brought it to a close during this year.

He accompanied me afterwards (Spring 1894) on a tour to the Mari country, which I undertook to study certain sections which Mr. Oldham had reported on previously (Records, Vol. XXV, pages 18 to 29). Mr. Smith was instructed to take up work in continuation eastwards of Mr. Oldham's surveys, and he has since geologically mapped some 2,000 square miles of very interesting country east and south-east of the sections which are reported on in the paper quoted.

Mr. Smith has shown considerable acquaintance with field-work, and has prepared a number of working sections, drawn to scale. These, with the map, will be published later on, when the survey of that country has been completed.

During November and December 1894, Mr. Smith continued his former work in the high hills east and south-east of Quetta, which have now all been examined, with the result of confirming in most cases my first conjectures, which I expressed in Memoir, Vol. XVIII, part 1. When I visited that country in 1880 a close study of the sections was impossible, owing to the disturbed state the frontier was in at that time, but I concluded from the general structure of the country, that the Takatu hill mass represented a section comprising both cretaceous and lower eocene strata; Dr. W. T. Blanford in his Memoir, Vol. XX, part 2, combated this view, having had better opportunities of studying this particular section. My view, however, has now been amply upheld by Mr. Smith's subsequent work, and not only have upper cretaceous rocks (with belemnites) been found to constitute the main mass of the Takatu hills, but also evidence has been produced of the presence of older (neocomian and jurassic) limestones with fossils. The uppermost portion of the hill-mass is lower nummulitic as represented in my memoir. A fault separates this section from younger eocene beds east and south-eastwards; this fault may be observed for some distance and forms one of the great structural features of Baluchistán.

Lala Kishen Singh was engaged in systematically collecting fossils from certain beds described by Mr. Oldham in the paper quoted above; in the end a very valuable collection of fossils has been brought together, which have since been examined and described by Dr. Noetling. The description will be published in the Palæontologia Indica as soon as the numerous plates can be lithographed; the manuscript is ready for the press.

The general result fully justified my original opinion that there is quite a sharp division between the cretaceous and eocene strata. The examination of the fossils proved also the existence of a distinct neocomian and below it, of a jurassic horizon. A local unconformity occurs above the neocomian.

The section at Mazár Drik, which is merely a type of numerous similar sections, is as follows in descending order:—

Middle / Lower } Eocene	6 Shales and sandstones.
	5 Grey limestone beds with *nummulites.*
Upper Cretaceous	4 Calcareous grit, shales and limestone with an abundant fauna of *cephalopods, echinoids, corals, foraminifera,* etc.
	3 *Belemnite* bearing series of shales and limestone beds.
	Local unconformity.
Neocomian	2 White and grey limestone with *belemnites.*
Upper Jurassic	1 Hard grey, thick-bedded limestone with a rich ammonite fauna.

In the spring of 1894, I instructed Kishen Singh to survey the area south and south-east of the Zarghún and south of the Harnai and Khóst hills on sheet 21-$\frac{SE}{4}$ of the Baluchistán survey, which he did satisfactorily,—in all 590 square miles.

I myself continued the work, which I had begun during the previous field-season; the ranges which divide the Quetta valley from the Pishin and the Kójak range were examined, and several traverses were completed, to settle the question of structure of these ranges. But there is still much to be done and it will require at least one more season's work to fill in the gaps on our geological map of the country west and north-west of Quetta. The first 4½ months of 1894 I devoted to the study and survey of the ranges which inclose the western Zhób valley, and especially the mass of hill-ranges between Loralai and Khanazai. This was a continuation of my previous field-season's work and the result is a fairly accurate geological survey of about 3,400 square miles, completed during the greater part of two seasons. In this part of Baluchistán, I could distinguish the following divisions of strata in descending order:—

Recent	(11) Alluvium; wide-spread deposits of sandy clays, conglomerates, and also in places, blown sands, which generally pass up imperceptibly from the next older formation.
Seistán formation Pleistocene	(10) Red and white sandy clays with sandstone and conglomerate beds, with much gypsum in layers and strings.
Miocene and pliocene	(9) Sandstone, shales, and conglomerate of the ordinary Siwalik type; fossil bones and casts of large *gastropods.*
Younger Eocene and Miocene	(8) Great thickness of sandstone beds, very like the Siwaliks in character, but with occasional limestone partings, which contain marine fossils.

Eocene.	Great development of basic igneous rocks. Intrusions of later date.	(7) Concretionary limestone and shales with fossils. (6) Sandstones, shales, and clay. (5) Thick limestone with *nummulites*.
Upper Cretaceous.	Interbedded basic rocks; gabbro, tufa.	(4) Limestone with *Sphenodiscus, Cardium Beaumonti*, etc., etc. (3) Shales and limestone with *belemnites*.
Neocomian . .		(2) Thick limestone with neocomian fossils.
Jurassic . . .		(1) Massive limestone with jurassic fossils.

Along a great line of dislocation which runs along the Chinjan and Yusuf Kats valleys, I have met with what I must consider genuine "blocs exotiques,"—of carboniferous and triassic rocks, bearing fossils. The dislocation is characterized by intrusions of basic rocks which obscure the position of these "blocs." It is hoped that more evidence of the same will be forthcoming during the next field-seasons.

One of the most remarkable features of Baluchistán geology is the association or igneous rocks with the upper cretaceous and the lower and middle part of the eocene deposits. The first outburstl of basic rocks, as far as can at present be ascertained, occurred in later cretaceous times; at least evidence of *intrusions* only have been met with in the jurassic beds, and even the lower part (limestones) of the upper cretacious seems free from interbedded igneous rock, but on the other hand these beds show locally great alteration near intrusions of the latter examples: Kach near Quetta, Gwál and other localities in the Zhób valley. The earliest evidences of contemporaneous igneous action occur in the upper cretaceous belemnite beds. This is seen clearest in the upper Zhób valley, especially near Gwál. Certain large areas of Baluchistán (south of Hindu Bágh and Kójak range) are entirely made up of great outbursts and spreads of basic igneous rocks, with gabbro and serpentine, associated with a few sedimentary beds, which are much altered in places and quite schistose in some. It is hardly possible to divide this complex of rocks, as precisely similar conditions seem to have continued right into middle eocene deposits. The higher portion of this facies, which may be compared to the Flysch formation of Europe, especially as developed in the Island of Elba,—contains a few beds of limestone which yielded *nummulites*, thus limiting the duration of igneous action to the period between the deposition of upper cretaceous and middle eocene beds. Quite unaltered limestone with upper eocene (Spintangi) fossils overlies the igneous facies of the northern Zhób and of the Kójak range. All trace of igneous action seems to have died out during that epoch.

The Kójak formation of shales, limestones and tuffaceous rocks,—in places quite schistose—I considered to be tertiary in 1880 (Memoirs, Vol. XVIII) and later in 1884 (Records, Vol. XVIII, page 59), as possibly cretaceous; probably both views are correct to some extent, and they may represent the igneous facies ranging from the upper cretaceous belemnite shales to middle eocene, and the formation may be a continuation westwards of the upper Zhób rocks. They are also associated with some irregular beds of limestone which contain large *nummulites*.

Connected with this great volcanic outburst are acid rocks, chiefly of the granitic family, which form part of the Khwája Amrán, and these may have been amongst the earliest eruptions which took place there.

Burma. Baluchistán. Dr. Fritz Noetling.

There are still a few questions of structural importance involved in the Yenangyoung oil-bearing tract and to clear up the same, Dr. Noetling was sent to Burma during this field-season. An exhaustive report on the oil-region will be brought out by him shortly.

During the hot weather and rains of last year Dr. Noetling examined and described the fine collection of cretaceous and jurassic fossils from Baluchistán which will be published as series XVI of the Palæontologia Indica.

Economic Geology.

During 1894, several officers were employed in practical investigations only, but in all cases where useful minerals were come across by the other parties engaged in field work, such occurrences have also been reported on.

Mr. LaTouche was during the past year, and is still, engaged in the trial boring for petroleum at Sukkur. Mr. Middlemiss has been engaged in the examination of the corundum and magnesite deposits of Madras.

Mr. Holland was employed in reporting on the Gohna landslip and has since been engaged in making numerous assays of minerals and rocks.

Mr. Smith surveyed the so-called "Quetta" coal-area, and has prepared a report which will be published. Dr. Fritz Noetling was deputed to report on the working of the Dandote and Warora coal-mines and has issued his reports on the same. He is now at Yenangyoung in Burma in order to finish his investigations of the oil-fields.

Mr. Grundy, the Inspector of Mines in India, has issued his first report for the year ending 1st July 1894, which has been printed and published. He has since inspected the mines in Mysore, Central Provinces and Rewah, and will proceed to Hyderabad (Dekkan), the Punjáb and Baluchistán.

Mr. William Anderson has been posted to Chota Nagpur to report on the supposed metalliferous belt of rocks.

Amongst the notes on useful minerals made by officers engaged in scientific surveys only, may be noticed reports by Mr. Bose on iron-ores, pockets of manganese, traces of copper and veins of argentiferous galena (61·60 per cent. lead and over 7 oz. of silver to the ton) in the Rewah State.

Mr. Datta reports on considerable quantities of an iron-ore in the Sone Valley, which is used locally for iron-manufacture.

Publications.

Considerable advance has been made in the publication of the Palæontologia Indica. Dr. Waagen has at last completed Vol. IV of series XIII, which deals with the ammonites of the ceratite beds of the salt-range. It is illustrated by 40 quarto plates and will appear shortly.

Series XV of the Palæontologia Indica has been commenced, and will illustrate the large and most important collection of fossils from the Himálayas, embracing not only the specimens preserved in the Geological Museum in Calcutta, but also every known specimen found in the Himálayas and preserved in the various European museums. Part 2 of Vol. II of this series is completed, and will appear shortly, illustrated by 31 quarto plates, descriptive of the Muschelkalk fauna of the Himálayas. Several other parts are in preparation.

Memoirs, Vol. XXV, on the geology of the Bellary district by R. B. Foote, is nearly ready for publication, and the final sheets are being passed for the press.

Vol. XXVI on the geology of Hazára by C. S. Middlemiss is in the press, and will appear shortly.

Vol. XXVII, Part 1 on the miocene fossils of Yenangyoung by Dr. Noetling, is in type and will shortly appear; Part 2 on the oil-fields of Yenangyoung is in manuscript, but will be ready for publication shortly after Dr. Noetling returns from Burma.

Museum and Laboratory.

Mr. Holland has re-arranged and labelled the collection of minerals to correspond with the more modern classification adopted in the new edition of Mr. Mallet's guide which has been re-written by Mr. Holland for the use of students. He also described a large number of rock specimens as contributions towards the work of classifying and arranging this portion of the collection. Where the description of the specimens has given promise of results of more than local petrographical interest, Mr. Holland has taken the opportunity of college vacations to work out their characters more fully in the field. In this way we have obtained a fairly comprehensive account of the distribution, and contact effects in the Bengal coal-fields of varieties of some new types of the remarkable group of peridotites. Amongst these the mica-peridotites which frequently contain anthophyllite and chromite are, from the excessive amount of apatite which they contain, most exceptional types amongst the known igneous rocks of the globe. The occurrence of these peridotites, which have now been found breaking through the lower Gondwana series in all the Bengal coal-fields, forms an interesting comparison with the peridotites which are similarly intrusive in the carbonaceous rocks of about the same age in South Africa. The large number of specimens of the peridotites and the altered and associated sedimentary rocks form a most instructive series in the Museum. In making this collection and in tracing out the field relations of the rocks, Mr. Holland has received most valuable help from Dr. Saise, Manager of the East India Railway Company's collieries at Giridih. (A detailed description of these rocks appears in Part 4 of Vol. XXVII of the Records).

Mr. Holland has described another new type of peridotite from the district of Manbhum which differs from previously known ones in containing hypersthene associated with olivine, augite, biotite and hornblende. (Records, Vol. XXVII, part 4.)

The mode of occurrence of the rare mineral columbite has been examined at Pananoa near Nawadih, East Indian Railway. Mr. Holland has found it in lumps imbedded in the quartz of a very coarse grained pegmatite dyke, intruded into a mica schist, which is crowded with tourmaline crystals.

The list of assays and determinations made in the laboratory has been published in the previous volume of the Records.

The work in the Museum was naturally interrupted during the early part of the year by Mr. Holland's absence at Gohna and Naini Tal, but he attributes the satisfactory progress which has been made largely to the valuable work done by the Museum Assistant, Mr. T. R. Blyth.

Whilst so much progress has been made in the mineral gallery of the Department, it is much to be regretted that the palæontological collection is in a most unsatisfactory state, both as regards arrangement of specimens and condition of the labels and cases. But this is entirely owing to the long absences of the Palæontologist of the Survey, who for some years past has been engaged on entirely different work, such as reporting on the mineral resources of Burma and the inspection of collieries in India. But it is hoped that he will be able to devote himself to more scientific work in future. A good beginning has been made by him in describing the miocene fossils of Burma and the cretaceous collections from Baluchistán, and we may reasonably hope to get the Palæontological Museum into order during the next two years.

There is much need of an efficient Assistant in that branch of the Department.

Library. The additions to the library amounted to 1,756 volumes, of which 777 were acquired by presentation, and 979 by purchase.

C. L. GRIESBACH,
Director, Geological Survey of India.

CALCUTTA,
The 31st January 1895.

List of Societies and other Institutions from which publications have been received in donation or exchange for the Library of the Geological Survey of India during the year 1894.

ADELAIDE.—Royal Society of South Australia.
ALBANY.—New York State Museum.
BALLARAT.—School of Mines.
BALTIMORE.—John Hopkins University.
BASEL.—Naturforschende Gesellschaft.
BATAVIA.—Bataviaasch Geonootschap van Kunsten en Wetenschappen.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—Deutsche Geologische Gesellschaft.
" K. Preuss. Acad. der Wissenschaften.
" K. Preuss : Geologische Landesanstalt.
BOLOGNA.—Reale Accademia delle Scienze dell' Istituto.
BOMBAY.—Meteorological Department, Government of Bombay.
" Natural History Society.
" Royal Asiatic Society.
BORDEAUX.—Société Linnéenne de Bordeaux.
BOSTON.—American Academy of Arts and Sciences.
" Society of Natural History.
BRESLAU.—Schlesische Gesellschaft fur Vaterländische Cultur.
BRISBANE.—Royal Geographical Society of Australia.
" Royal Society of Queensland.
BRISTOL.—Bristol Naturalists' Society.
BRUSSELS.—Acad. Roy. des Sciences.
" Société Belge de Geographie.
" " Roy. Malacologique de Belgique.
BUDAPEST.—Kön. Ungarische Geol. Anstalt.
BUENOS AIRES.—Acad. Nacional de Ciencias en Cordoba (Republica Argentina).
CAEN.—Société Linnéenne de Normandie.
CALCUTTA.—Agricultural and Horticultural Society of India.
" Asiatic Society of Bengal.
" Editor, Indian Engineering.
" " The Indian Engineer.
" Indian Museum.
" Meteorological Department, Government of India.
" Royal Botanic Garden.
" Survey of India.
CAMBRIDGE.—Philosophical Society.
" University of Cambridge.
CAMBRIDGE, MASS.—Museum of Comparative Zoölogy.
CASSEL.—Verein für Naturkunde.
CHRISTIANIA.—Committee, Norwegian North Atlantic Expedition.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Kong. Danske Videnskabernes Selskab.
DEHRA DUN.—Great Trigonometrical Survey.

DES MOINES.—Iowa Geological Survey.
DRESDEN.—Naturwissenschaftliche Gesells. Isis.
DUBLIN.—Royal Irish Academy.
„ „ Dublin Society.
EDINBURGH.—Geological Society.
„ Royal Scottish Geographical Society.
„ „ Scottish Society of Arts.
„ „ Society.
FLORENCE.—R. Biblioteca Nazionale Centrale di Firenze.
GLASGOW.—Glasgow University.
„ Philosophical Society.
GOTHA.—Editor, Petermann's Geographische Mittheilungen.
GÖTTINGEN.—K. Gesells. der Wissenschaften.
HALLE.—Academia Cæsarea Leop.-Carol. Naturæ Curiosorum.
HAVRE.—Société Géologique de Normandie.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Société Vaudoise des Sciences Naturelles.
LEIDE.—École Polytechnique de Delft.
LEIPZIG.—Verein für Erdkunde.
LIÈGE.—Société Géol. de Belgique.
LILLE.—Société Géologique du Nord.
LISBON.—Section des Travaux Géol. du Portugal.
LIVERPOOL.—Geological Society.
LONDON.—British Museum.
„ Geological Society.
„ Iron and Steel Institute.
„ Linnean Society of London.
„ Royal Geographical Society.
„ Royal Institute of Great Britain.
„ Royal Society.
„ Society of Arts.
„ Zoölogical Society.
MADRID.—Sociedad Geografica de Madrid.
MANCHESTER.—Geological Society.
„ Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water-Supply, Victoria.
„ Royal Society of Victoria.
MILAN.—Societá Italiana di Scienzé Naturali.
MOSCOW.—Société Imp. des Natur.
MUNICH.—Kon. Bayerische Acad. der Wissensch.
NAPLES.—Reale Accademia delle Scienze Fisiche e Matematiche.
NEWCASTLE UPON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Editor, "American Journal of Science."
NEW YORK.—Academy of Sciences.
OXFORD.—University Museum.
OTTAWA.—Geological and Natural History Survey of Canada.
PARIS.—Editor, Annuaire Géologique Universel.
„ Commission des Mines.

PARIS.—Ministere des Travaux Publics de la Carte Géologique de la France.
„ Société de Geographie.
„ „ Géologique de France.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Societa Toscana di Scienze Naturali.
RIO-DE-JANEIRO.—Imperial Observatory.
ROCHESTER.—Geological Society of America.
ROME.—Reale Accad. dei Scienze.
„ „ Comitato Geol. d'Italia.
SACRAMENTO.—California State Mining Bureau.
SAINT PETERSBURG.—Comité Géologique.
„ Russische Mineralogische Gesellschaft.
SALEM.—Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—China Branch of the Royal Asiatic Society.
SPRINGFIELD.—Illinois State Museum of Natural History.
STOCKHOLM.—L'Institut Royal Geol. de la Súede.
„ Kongliga Svenska Vetenskaps Akademie.
SYDNEY.—Australian Museum.
„ Department of Mines and Agriculture, New South Wales.
„ Geological Survey of New South Wales.
„ Linnean Society of New South Wales.
„ Royal Society of New South Wales.
TOKIO.—Deutsche Gesellschaft für Natur und Volkerkunde.
TORONTO.—Canadian Institute.
TURIN.—Reale Accad. delle Scienze di Torino.
„ Regia Universita di Torino.
VENICE.—Reale Istituto Veneto di Scienze.
VIENNA.—K. Akad. der Wissenschaften.
„ K. K. Geographische Gesellschaft.
„ K. K. Geologische Reichsanstalt.
„ K. K. Naturhistorisches Hof-Museum.
WASHINGTON.—National Academy of Sciences.
„ Smithsonian Institution.
„ United States Geological Survey.
„ „ „ Mint.
„ „ „ National Museum.
WELLINGTON.—New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ Seismological Society of Japan.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Naturforschende Gesellschaft.
The Governments of Bengal, Bombay, India, Madras, and the Panjáb.
The Chief Commissioners of Assam, Burma, and the Central Provinces.
The Residents, Hyderabad and Mysore.

The Cretaceous Formation of Pondicherry by H. WARTH, D. SC., (Tübingen), *Deputy Superintendent, Geological Survey of India.*

The area which I was deputed to examine during January and February 1894, had last been visited by the late Mr. H. F. Blanford in 1860, and was described by him in Vol. IV, p. 156 of the Memoirs. It is situated between the Red Hills of Pondicherry on the south-east and between what Mr. Blanford called the Tirvukarai ridge on the north-west, and is bounded on the south-west by the alluvium of the Ariankupam river. The total length is about 8, and the width 4 miles. A large surface of this ground is occupied by numerous tanks or artificial reservoirs for rainwater, used for irrigation. Most of the area consists of level and cultivated fields, amidst which are a few isolated exposures of rock *in situ*. It is not nearly as favourable for study as are the cretaceous sections near Trichinopoly; there the exposures of strata on eroded patches measure square miles, whereas in the Pondicherry area they amount to acres or even square yards only. This great paucity of exposures has been repeatedly pointed out by Mr. H. F. Blanford, and if, notwithstanding this, the first explorers, Messrs. Kaye and Cunliffe obtained such large numbers of valuable fossils in 1840, it will be shown further on how this may be accounted for.

Mr. H. F. Blanford showed that the cretaceous strata may be separated into two distinct divisions: the lower he named the Valudayur group, which hitherto has been considered to be equivalent to the Utatur group of Trichinopoly, whilst the upper series he found to be identical with the Ariyalur group of Trichinopoly.

Considerable confusion has taken place in the collections made in Pondicherry, and the object of my visit to that area was not only to obtain a large number of fossils, but to establish them in the various horizons. I have succeeded not only in separating the fossils according to the two main divisions, but I have been able to distinguish three successive horizons in each of these divisions. We have, therefore, altogether 6 horizons from which fossils have been obtained, the three lower of which constitute Mr. H. F. Blanford's Valudayur group, whilst the three upper ones are what he accepted as Ariyalur group. As will be shown later on, the whole of the strata must now be considered as Ariyalur group.

The bedding of these horizons is either horizontal or a gently dipping towards south east. The general lithological character of all the beds is that of sand or sandy clay with calcareous nodules or concretions which are scattered throughout the whole formation. Only the uppermost horizon contains a continuous thin layer of limestone in addition to concretions.

Horizon A.

Horizon A is the lowest sub-division and appears on the surface as a strip 2 miles wide. It is separated from the Tirvukarai ridge by a band of alluvium 1½ miles wide which conceals all outcrops. Going from north-west to south-east, the first indication of the horizon consists of white sands with nodules of one foot thickness. These nodules or concretions contain traces of annelid channels only. They are also stained with dendritic manganese. The localities examined are well-exacavations, ¼ mile east-south-east of Lingaredipaliam and 1 mile north-east of Katarampokam.

Next in ascending order we observe yellow sands with gravel, 1 mile east-north-east of Katerikupam in the bed of the canal, and in the ravine 1 mile north-east of Vanur. The latter place is referred to by Mr. H. F. Blanford on page 157 of his Memoir.

Lastly, we have sandy clays with large concretions, which contain; annelid casts, they have a diameter of ½ inch, and some were up to 6 inches in length. They are usually curved. The concretions consist of crystalline calcite with a distinctly botryoidal surface. They are usually somewhat lenticular, 2 feet thick, and of 3 feet diameter. I have searched for them in vain in the neighbourhood of the Ariankupam between Valudayur and Muterampatu, but the concretions are well exposed at the following three localities which are on the same strike, from south-west to north-east:—The first is near Katerikupam, where the concretions show along a length of over ½ mile of the canal excavation. The blocks had about 2 feet diameter and the surfaces were decidedly botryoidal, proving their concretionary origin. The second locality is about ¾ miles south-west of Vanur; the concretions are shown very clearly in several square wells. They form layers which have a slight inclination towards the south-east. Many of the lenticular concretions had about 1½ feet thickness and 3 feet diameter with botryoidal surfaces. In one well were so many concretions and so close together that they presented the appearance of a continuous bed of limestone, 2 feet thick. The concretions contain numerous annelid burrows. I broke up one of the blocks entirely without finding a trace of any fossil. In the neighbouring fields were also scattered blocks of the same kind. Near the village of Wattai close by, is a large square tank which is lined with the same blocks said to have been derived from the excavated tank bed. Many blocks of the concretions from horizon A are also seen in the lining of other tanks in the neighbourhood, for instance at Vanur. But in the latter many stones had been used, which must have been brought from near Saidarampet in French territory, and belong possibly to horizon E, and are usually fossiliferous. It is not easy to distinguish always the different blocks from each other. But those from horizon A have no fossil shells and are botryoidal, whilst certain fossils show others at once to have been derived from horizon E. The third place is the best of all the exposures. It is immediately south of the village of Andipaliam, where many concretions are exposed on the surface. One of them was 2 feet by 4 feet by 6 feet. The concretions formed layers with a moderate dip to the south-south-east, many of them were also washed out of the matrix, but most probably are very near their original site. Some of the concretions contained quartz pebbles about 2 inches in length arranged in layers.

I observed also some concretions about half a mile south-east of Olundiapati, in which I have not found any fossil, but which I am inclined to include in horizon A.

Horizon B.

The next higher horizon B contains fossiliferous concretions and has also yielded some fossils from the sandy matrix. I include herein the exposure of yellow sands in a tank-bed, 1 mile south-east of Vanur. At that place I found many minute bivalves and a few distinct *Baculites vagina*. On the Vanur Pondicherry road, 1 mile north of Saidarampet, small bivalves occur in a white sand, which I include in B, although it is in contact with scattered blocks of horizon E. I also include with B large, slightly fossiliferous concretions and nodules, 1 mile south-south-east of Pulichapaliam. In the road ditch and in some wells east of the road, I found fossiliferous concretions of large size, of which one has yielded a small *ammonite.*

Horizon C is the most important of all, as it seems most probable that from it were derived the cephalopods which Messrs. Kaye and Cunliffe obtained about the year 1840. The spot from which most of these fossils appear to have come is north-north-east of Valudayur and north of Tutipet. It is from this place that I obtained the best fossils of horizon C, but some I found further north-east close to the village of Rautankuppam. I found in this horizon four small *ammonites*, several species of *Hamites*, *Baculites vagina* in numerous well preserved specimens, many *lamellibranchiata*, *gastropoda*, etc. The list at the end of this paper refers to preliminary identifications by Dr. Kossmat.

Horizon C.

The fossils occur in blocks which are not *in situ*, but washed out of the alluvia ground, and are largely used for building purposes, so that the supply is really limited. I have now used up all the loose blocks which I could see, and I doubt whether more will be found for a considerable time to come. Mr. H. F. Blanford considered the place already exhausted, as will be apparent from his remarks on pages 154, 155, 156, 158, 163, Memoirs, Vol. IV, and page 2 of his account of Cretaceous Cephalopoda in the *Palaeontologia Indica.*

Mr. Blanford referred at some length to the ridge east of Valudayur on which he traced the boundary between his Valudayur group and the overlying Ariyalur group. This ridge is not a very prominent object in the landscape, and some of the exposures on it, which Mr. H. F. Blanford described, must since have disappeared. If the Topographical Survey map had been provided with contour lines, this ridge as well as the Tirvukarai and Red hills ridges would be clearly shown, but although this is not the case, the ridge in question is marked by the space which it occupies between two rows of irrigation tanks, and a line drawn on the map from Tutipet to Akasampatti travels along the centre of the ridge. It rises about 115 feet above the sea and thus about 45 feet above the cretaceous area to the north-west of it and 89 feet above the level of the great Usteri tank lake to the south-east. Near Tutipet and Valudayur, the north-west base and part of the slope of the ridge comprises horizon C. Towards north-east the ridge merges more or less into the more elevated country, and the exposure of horizon C near Rautankupam is on nearly level ground. As will be seen hereafter, the south-east slope of the ridge about Tutipet, Karasur and Saidarampet coincides with the harder beds of the horizon F, and it is very probable that these limestone banks have been the cause of the preservation of the ridge.

The horizon D is characterized by a continuous bed of sandy shale, several feet thick, which is full of casts of shells, most of them those of *lamellibranchiata*, *Trigonoarca Galdrina*, *Macrodon Japeticum*, *Alectryonia ungulata*, etc. Others will be found on the list at the end. I also found a few *ammonites* and *Baculites vagina* and some specimens of *nautilus* two feet in diameter. A few specimens of *terebratula* were also found in this horizon, also some *corals* and *echinoidea*. Small fish teeth were numerous.

Horizon D.

A fact of importance is the wholesale conversion of shells into phosphate, or rather the production of interior casts of shells consisting of rich black phosphate.

Some of the casts show also the impression of honey-combed cells one-fiftieth of an inch in diameter, most likely due to bryozoa. In this same stratum are also numerous concretions of light brown colour, which are likewise strongly phosphatic; they are of irregular shapes, resembling some organic structure.

I found three very clear exposures of this horizon. The first in a well, a quarter of a mile west-south-west of Tutipet, the second is *in situ* on the surface of the road a quarter of a mile north of Karasur, the third is in a well a quarter of a mile west of Rautankupam on the west side of the Tindivanam Pondicherry road. A small exposure was also noted in a well, a quarter of a mile north-west of Royapudupakam. In the Rautankupam well the sandy bed, which contains the casts of shells, is also partly replaced by concretions of one foot thickness, in which fossils occur.

Phosphatized shells are not found in any of the other horizons, with the exception of the lowest portions of horizon E. There are some phosphatic cores of light color in the centre of gastropods, in nodules of the upper part of horizon F. But these cores are of quite different appearance to the phosphatic matter in D, and in much smaller quantity. The black phosphatized shells are a sure indication of horizon D and the overlying portions of horizon E. They are seen in several places scattered over the fields mixed with other fossils, where no distinct exposures of the strata are otherwise seen.

Horizon E.

This horizon is important on account of the large number of nodules of shell limestone it contains. A very great number of the nodules have been utilized for tank revetments and buildings in the neighbourhood. Many were also used for walls, buildings and pavements in Pondicherry. The pavement shows all the various fossils of the horizon in sections. One fossil is especially very prominent and characteristic. It is a coral, *Cyclolites filamentosa,* which is seen in semicircular sections. *Exogyra ostracina* is also common. Owing to the systematic removal of blocks from the surface of the outcrop, it is generally difficult to trace the area of horizon E, but at a place near Karasur I still saw the blocks being quarried, and one very large deposit of blocks is exposed *in situ.* There is also an outlier of this deposit consisting of some 40 blocks, at a point 1 mile north of Saidarampet. The worn surfaces of the blocks show sections of numerous fossils, which contrast strongly against the brown matrix. Besides *gastropoda* and *lamellibranchiata* in great numbers, the sections also show the semicircular or crescent shaped outlines of *Cyclolites filamentosa,* which coral is most characteristic of horizon E.

The wall of a tank near the village of Royapudupakam yielded numerous fossils as has already been pointed out by Mr. Blanford. Amongst them I collected *Exogyra ostracina, Alectryonia ungulata, Euptycha larvata, nautilus, etc.* Some of the fossils are also found in horizon D and with them were also some black phosphatic nodules.

Horizon F.

The uppermost horizon is characterized by fucoid casts, which are cylindrical and about three quarter of an inch thick and generally in broken pieces of about five inches length; some of these casts are bifurcated. They are much used for lime burning, along with calcareous nodules found in the same bed. The latter are about two inches diameter and contain spiral *foraminifera* of minute size; they are dug up from the soil which overlies some of the fucoid limestone.

The same yellow, crystalline, somewhat sandy limestone was found exposed at the Usteri canal, one mile south-south-east of Valudayur and half a mile along that canal towards south-east; at four places on the way thence to Kadaperikupam; at the kilns half a mile south-west of Kadaperikupam; at Kadaperikupam; at Saidarampet; at the kilns quarter of a mile east-north-east of Saidarampet; half a mile west of Akasampati; quarter of a mile east-south-east of Akasampati; quarter of a mile south of Wattampalliam (French part of village called Sanjiverampet), and lastly in the bed of a large open tank near Royapudapakam.

The limestone is the only continuous bed of hard rock in the Pondicherry cretaceous. At the Usteri canal I estimated the total thickness to be five feet of limestone, with partings of sand. At Saidarampet a solid bed of limestone showed two feet thickness with a dip of four degrees south-east.

Most of the fossils are obtained from the overlying sands. Amongst them are some very characteristic corals (*Coryophylla arcotensis*, *Cyclolites conoidea*), *Teredo* tubes in abundance and very large gastropods (cones of one foot length), *Nautilus serpentinus* and one nautilus with a very sharp keel, apparently a new species.

The limestone dips generally towards south-east, the surface of the country coinciding with the dip slope. Above the limestone, clays and sands with nodules continue. One clay bed with layers of nodules has already been mentioned as containing some shells with light coloured phosphatic cores. In this bed remains of a turtle were found. Still higher up in the series large concretions of two feet diameter are seen in an excavation one mile north of Tirusitambalam (at the road fork). Near Tirusitambalam I noticed yellow clays with minute bivalves, and similar clays continue up the side of the Red hills ridge. These were no doubt the upper-most cretaceous deposits mentioned by Mr. H. F. Blanford, page 160, Vol. IV.

These six horizons represent the whole sequence of the cretaceous strata.

A line of section.

With the exception of horizon F the exposures of the strata are very few and it would be difficult to find a continuous sequence. But there is, however, a line of section, in which four horizons are well represented and the other two at least indirectly. This is along the Tindivanam Pondicherry road. Starting at a place 12 miles from Pondicherry, we obtain a fair section along a straight road of about 4½ miles length, along which exposures of most of the horizons are seen.

Dip of strata.

The general dip of the sequence of beds was given by Mr. H. F. Blanford as two degrees, which accords with my own observations.

Thickness.

The total thickness of the cretaceous rocks of Pondicherry may be about 900 feet.

Preliminary table of fossils.

The fossils obtained were sent to Vienna for determination and they have since been examined by Dr. F. Kossmat of the University of that city. He will describe the collection in detail, but has given the annexed preliminary list of fossils.

Preliminary List of Fossils.	Horizons.				
Caryophyllia arcotensis Forb.	...	...	...	...	F
Cyclolites conoidea Stol.	...	...	...	...	F
Hemiaster, n. sp.	...	...	D	...	...
Stigmatopygus elatus	...	C	...	...	...
Terebratula arabilis, Forb.	...	...	D	...	...
Alectryonia ungulata, Schl.	...	C	D	E	...
Exogyra ostracina, Lam.	...	...	...	E	...
Gryphaea vesicularis	...	...	...	...	F
Plicatula	...	...	D	...	...
Spondylus, n. sp.	...	...	...	...	F
Spondylus calcaratus, F.	...	...	D	...	...
Pinna cf. laticostata, Stol.	...	C	...	...	...
Modiola flagellifera, Forb.	...	C	...	...	...
Modiola polygona, Forb.	...	C	...	...	...
Macrodon Japeticum, Forb.	...	...	D	...	...
Trigonoarca sp.	...	C	...	...	...
Trigonoarca Galdrina, F.	...	C	D	E	...
Cyprina cristata, Stol.	...	...	D	...	...
Protocardium bisectum, Forb.	...	C	...	...	...
Panopaea orientalis, Forb.	B	C	...	...	...
Pholadomya caudata	B	C	D	...	...
Corimya pertusa, Stol.	...	C	...	...	...
Pharella obscura, Forb.	B	C	...	...	...
Teredo aff. glomerans	...	...	...	...	F
Phasianella cf. conulata, Stol.	...	C	...	...	...
Euspira sp.	...	...	...	E	...
Euptycha larvata, Stol.	...	...	...	E	...
Nerita sp.	...	C	...	...	...
Nerita divaricata, Orb.	...	C	D	E	...
Turitella sp.	...	...	D	E	...
Cerithium, n. sp.	...	...	D	...	F

PRELIMINARY LIST OF FOSSILS.	HORIZONS.				
Nerinea, n. sp.	...	...	...	...	F
Cypraea Newboldi, F.	...	...	D	...	...
Cypraea sp.	...	...	D	E	...
Cypraea Kayei, Forb.	...	...	...	E	...
Rostellaria palliata, Forb.	...	C	...	...	...
Athleta purpuriformis, Forb.	...	C	...	...	...
Nautilus sp.	...	...	D	E	F
Nautilus aff. Bouchardianus	...	...	...	E	...
Nautilus cf. serpentinus, Blanf.	...	...	...	...	F
Nautilus sphaericus, Forb.	...	...	...	...	F
Lytoceras sp.	B	...	...	...	...
Hamites subcompressus, Forb.	...	C	...	...	...
Hamites indicus, Forb.	...	C	...	...	...
Hamites tenuisulcatus Forb.	...	C	...	...	...
Ptychoceras sypho Forb.	...	C	...	...	...
Baculites, sp.	...	C	...	...	...
Bacolites vagina, Forb.	...	C	D	E	...
Desmoceras sp.	...	C	...	...	...
Pachydiscus ganesa, Forb.	...	C	...	...	...
Pachydiscus species	...	C	D	...	...

The fauna.

Dr. Kossmat intends giving a fuller description of the fossils later on, but I am authorized to state that he considers the Pondicherry cretaceous series to belong to the Ariyalur division. I may also remark here that these fossils have confirmed this conclusion, which Dr. Kossmat had already arrived at from other evidence; he had compared the original type specimens of the cepalopods of the Utatur and of the so-called Valudayur groups and had also discovered new points of agreement between the fauna of the Ariyalur group of the Trichinopoly area and the Valudayur group, and also with the cretaceous fauna of Natal. The Valudayur group will cease to be so distinguished and the horizons A, B, C, will have to be considered to be lower Ariyalur only

Some early allusions *to* Barren Island; *with a few remarks thereon, by* F. R. MALLET, F. G. S., *late Superintendent, Geological Survey of India.*

When writing the description of Barren Island that appeared in the twenty-first volume of the Survey Memoirs, I was unable to refer to any accounts of the Volcano earlier than that by Lieutenant Colebrooke, who saw it from a distance in 1787, and that by Captain Blair, who landed during a violent eruption in 1789[1]. The name 'Barren Island,' however, was not originally given by either of those observers: it had been applied before their time to the Volcano, which, by some, had also been called 'Monday' and 'High' Island. It was clear, therefore, that the island was more or less known before Blair's visit, and it seemed possible that some one or more accounts of it, by navigators who had seen, or even landed on it, might be in existence, and that perchance some allusions to its volcanic condition earlier than those mentioned above, might be on record. I have recently taken advantage of residence near London to try whether any such accounts could be found, and with this object in view, have made a somewhat laborious search at the libraries of the India Office, the British Museum, and the Public Record Office. The examination of a very large number of printed works and manuscripts has, I am sorry to say, not led to the acquisition of a corresponding amount of new information, and there can be little doubt that there still exist accounts which remain to be discovered. But the following records, however meagre, at least add something to our knowledge of the volcano.

Van Linschoten, 1595.

The earliest indication of the island being known, that I am aware of, is to be found in the original Dutch edition of Van Linschoten's[2] voyages[3]: this work contains two maps engraved in 1595, one of India and some adjoining countries, the other of the Malay Peninsula and archipelago[4]. The 'Andemaon' and adjacent islands are included in both, the configuration in one being identical with that in the other. 'Nacondaon' is placed in lat. 14° 20'. No longitudes are given, but the position is 90 miles[5] E. or E. ½ N., from the northern end of the Andamans. About 45 miles S. by E. from "Nacondaon" (Narcondam), in Lat. 13° 35', there is a nameless island which is much nearer the true latitude of Narcondam (13° 26') than that to which the name is attached, and it is probably a duplication of that island, through a discrepant, and more accurate, determination of its position.[6]

1 Asiatic Researches, Vol. IV, p. 397.

2 Erroneously printed "Linschten" in Memoirs, G. S. I. Vol. XXI, foot-notes to pages 264 and 285.

3 "Itinerario Voyage ofte Schipvaert, Van Jan Huygen Van Linschoten naer oost ofte Portugaels Indien," etc., Amstelredam, 1596.

4 Facsimiles of these maps (but with the Dutch titles, etc., rendered into English) are included in "John Huighen Van Linschoten, his Discours of Voyages into ye Easte and West Indies," London, 1598, a translation of the original work.

5 Here, and elsewhere, the miles given are nautical ones.

6 On a "Chart of the Bay of Bengal," contained in the "East India Pilot, or Oriental Navigator," and dated 1778, or nearly two centuries later than Linschoten's maps, "Narcondam of the Portuguese"| is marked in Lat. 13° 47' and "High I. or Narcondam of the

A second small and nameless island is marked about 45 miles east of the Andamans, in Lat. 12° 25′. This is some 10 or 12 miles N. W. from the true position of Barren Island, for which, I think, there can be no reasonable doubt that it is meant, as there is no other land for which it can possibly be intended.

Linschoten makes no mention of having himself visited the Andaman Islands. In the titles of the above named maps it is stated that they were "perfectly drawne and examined with the most expert cardes of the Portingales Pilots," which suggests that the island just mentioned were inserted on Portuguese authority as the explorer who charted them thought Narcondam worthy of a name on the map. Perhaps if Barren Island had been in eruption, and thus specially attracted his attention, he would have attached one to it also.

On many charts of much later date than Linschoten's, no land near the position of Barren Island is indicated. Hence it was a new discovery to Captain H. Gough, when he sighted it in 1708.

Gough, 1708.

The log of his ship, the Stretham, is preserved at the India Office. On the 17th December of the year just mentioned, the following entry was made:—"Now at sunrise we see Land[1] from W. b. N. to N. W. b. N., at 7 o'clock ye squall being over we had an Island appearing thus" (small sketch given); "then ye other land bore from W. to N. W. by W. distance, I judge, 10 or 12 leagues. Now we have no drafts[2] that anything answer these bearings; therefore I commenced one From ye Lat. 11° which will include ye shoall,[3] to Lat. 14°, which will carry me to ye Cocos Islands; see the other side." The last sentence refers to Gough's M. S. chart,[4] on which the island, without any name, is marked in Lat. 11° 53′, and 58 miles E. S.E. from the Andaman coast. It is about 23 miles south of the true position of Barren Island, an error which is probably due to the fact that while Gough obtained his latitude on the 16th by observation, that on the 17th was by "account." There is, however, a discrepancy between the log and the chart. In the former his latitude on the 17th is given as 12° 30′, while on the chart his position at noon is marked in Lat. 12° 18′. If this difference were applied to the island, it would bring its latitude within 11 minutes of the correct one.

The island when seen was at a distance of 8 or 10 leagues to the E. S. E., and

French" 45 miles to the S. E. by E. in Lat. 13° 20′. On "a general map of the East-Indies" (1781), contained in the same Atlas, "Narcondam according to the Portuguese" is marked in Lat. 13° 45′, and "Narcondam or High Island according to the French," 60 miles to the S. by E. in Lat. 12° 50′. The French Island is certainly not intended for Barren Island, although the latter, as previously remarked, has also been known under the name of High Island. (See remarks, further on, about the "Flat Islands," and *cf.* Memoirs G. S. In Vol. XXI, foot-notes to pages 264 and 285). I have not succeeded in finding any original accounts of the Portuguese or French observations.

[1] The Andaman Coast.

[2] The obsolete term for chart.

[3] The "Flat Rock, awash" of the Admiralty chart (lat. 11° 8′). Capt. Gough puts it in 11° 10′, and on the 14th December writes :—Now as we rose from dinner we see Breakers N. N. E. of us nothing appearing above water. I suppose them 7 or 8 miles of as they broke high. We tacked. This shoall we find in our Drafts as to Latitude, but its laid not above 7 leagues off ye little Andemons and we see them not."

[4] Scale 3½ inches to 1° of latitude. A copy, on a reduced scale, is included in Dalrymple's Plans and Charts.

measures on the chart about 4 miles × 2, with the length perpendicular to the line of sight; but this was evidently a mere eye-estimate.

There is a rough free-hand sketch of the island in the log, from the point of view just mentioned, which represents it as a very high one,[1] with the culmination near the S. S. W. extremity, a nearly flat top inclining gently towards the N. N. E., and steep slopes at the ends exactly the appearance which Barren Island, at the present time, would have, if viewed from the same position,[2] except that the height, in proportion to the breadth, in the sketch,[3] is a good deal more than in nature. This is so obviously due to exaggeration, which might, perhaps, be almost expected in a rough outline evidently dashed off *currente calamo*, that it would be waste of space to raise the question whether the valcano really was much higher in 1708. Had such been the case indeed, the truncation of the ancient cone must necessarily have been far less than is implied by the sketch, and the latter would entirely fail to represent the facts.[4] There is no indication, in the sketch, of smoke[5] rising from the volcano.

Various observers.

Reference to the observations of several navigators may be found in a "Memoir of a chart of the Indian Ocean," 1787 (contained in the first volume of Darlymple's Nautical Memoirs), where at page 36 we read:—

"The Island, called *Barren Island* by Capt. Taylor and Capt. Justice, *Monday Island* by Cheyne, from old Draughts; and *Alto* by Capt. Baker and C. Alves[6] is in

Lat.	12°20′ N.	by C. Mills, 1758.
	12 22	Alves, 1760.
	12 20	Justice, 1771.
	12 20	Taylor, 1780.

Long. by Capt. Taylor's observations of Sun and Moon 93° 10′E. from Greenwich."

Cheyne, 1748.

The log of Capt. Cheyne's ship[7] (the Lapwing) shows that Cheyne passed "Monday" (Barren) Island, at the close of October 1748, and saw it from various points of the compass, but he made no nearer approach than 8 or 9 leagues. His observed latitudes on the 28th and 29th, combined with the bearings and estimated distances of the island, respectively made it in lat. 12° 6′ and 12° 16′. He remarks that "this by some is called Monday Island, but we have no account of it in the draught."

[1] The greatest elevation, as measured by Capt. Hobday in 1884, is 1,158 feet: therefore allowing for curvature and refraction, the island at a distance of 8 leagues would rise more than 700 feet above the horizon, while at 10 leagues it would still rise nearly 500.

[2] *cf.* Capt Hobday's sketch, in the corner of his map (Memoirs, Vol. XXI), taken from nearly the same bearing, but much nearer the volcano.

[3] One to five, which, under the circumstances of distance mentioned, would indicate a height of more than 2,000 feet if the sketch had been drawn accurately to scale.

[4] *cf.* Remarks, in the succeeding paper, as to the probable antiquity of the truncation.

[5] A convenient term, and quite as accurate as cinder and ash, in connection with volcanoes.

[6] "Barren Island, still smaller than Narcondam, is called likewise *Monday Island*; and by the Portuguese *Ilha Alta* (High Island)." 'The Oriental Navigator,' by J. Purdy, London, 1826, page 350. The information in this work about the Andamans is of somewhat old date and "extracted chiefly from Capt. Richie's account."

[7] India Office Records.

In the year 1758, Captain Mills, of the Drake, noticed "Land even with the water" in Lat. 11° 12′, and "he says the land and (Alto, which he calls) *Arracondam*, bears of each other N. b. E. ½ E. and S. b. W. ½ W. distant 21 leagues,"[1] which makes the latitude of Alto (Barren Island) 12° 12′, or within 4 minutes of the now accepted value. This quotation is of interest from the name Arracondam (presumably a corruption of Narcondam) being applied to *Barren Island.* Although I do not think Captain Mills' application of the name can be taken as proving anything, as he probably so used it through imperfect information, still the point is worthy of notice in connection with the origin of the term Narcondam alluded to in my memoir on the volcanoes.[2]

Mills, 1758.

I have not met with any record by Captain Alves or Baker. The discovery of a dangerous rock was reported by Captain Justice in 1771, which he describes in some detail[3] and at the conclusion says "Imagining I was to the westward of the Little Andaman I stood to the N. N. E.—ward in order to get its true place, but on the 2nd November, at 6 o'clock in the morning, I was surprised to see *Barren Island;* it lays by my account, not allowing the current, to be 20 miles to the westward of Barren Island[4] in the latitude of 11·07 or 11·12."[5]

Justice 1771.

The following remarks by Captain Taylor[6] of the Ship 'Ceres' are perhaps worth reproduction in full, as illustrative of the inaccuracy and uncertainty that prevailed about Barren Island until late in the last century:—

Taylor 1780.

× × × × ×

"January 12" (1780), "per medium of 13 good sights of the longitude found ourselves in 93° 36′ longitude from Greenwich, which is 1° 33′ W. since last sights and by the charts is nearly the longitude of the Islands, laid down in 12° and 11° 30′ N. Lat. by the name of *Barren Island.* Kept a very good look out in the night and sounded as per log; next morning at daylight saw a pretty large Island bearing N.E. ½ E., 10 leagues, the ext. of the *Andamans* (just in sight) from W.N.W. to S.W. by S., 9 or 10 leagues. Till noon, that we had a good observation, could not determine whether the Island in sight was the northernmost *Barren Island* or *Narcondam;* we observed in 11° 59′ N., the lat. of the northernmost *Barren Island* as laid down in the charts; the Island bearing N.E. by N. between 8

[1] Memoir of a Chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[2] Page 284.

[3] He was not, however, the original discoverer of the danger, which was seen by Gough in 1708, and alluded to by him as previously known.

[4] *i.e.* the rock is 20 miles west of the meridian of Barren Island.

[5] M. S. Bengal Public Consultations, India Office Records; and Memoir of a Chart of the Indian Ocean, 1787, (*op. cit.*), p. 36. I may mention here, incidentally, that the earliest illustration of Narcondam I have met with, is to be found on a "Chart from Negrais to the Island Carnicobar, by John Richie, 1771" (Dalrymple's Plans and Charts), as might be anticipated in respect to an extinct volcano; this sketch ("Narcondam, bearing E. by S. distant 7 miles"), shows no perceptible variation from the present outline. On this Chart Barren Island is not indicated.

[6] Dalrymple's Nautical Memoirs, Vol. II.

and 9 leagues distant which makes it come nearest the lat. of Barren Island. A day or two afterwards by a very good observation within 2 or 3 miles from the northern end of it, find its latitude to be 12° 20′ northern (21 miles to the northward of its situation upon the Charts)[1] and its longitude, by several very good observations of the Sun and Moon, to be 93° 10′ E. from Greenwich.

The nearest of the *Andaman* Islands we could see bearing S.W. by W. from it 18 or 20 leagues. As for the southernmost *Barren Island* we concluded that it did not exist, or if it did, that it must be very erroneously placed in the charts, for the day after we saw *Barren Island* we were set to the southward in endeavouring to pass to the eastward of it, and at noon had the Island bearing from N.b.W. to N.N.W., 12 leagues and observed in 11° 48′ N., which is nearly the southernmost *Barren Island* (as laid down) notwithstanding which, saw no such Island although the weather was very clear; since which time I was informed by the Captain of a Portuguese schooner that he had seen both the Islands, the southernmost being situated much further to the westward than laid down.

"I likewise have it from good authority that Captain Sharrington of the Bahar country ship saw the rocks under its ship's bottom and sounded in 4 fathoms *Barren Island* being N.N.W. 5 or 6 leagues. In the charts there is some dangers laid down[2] to the southward of the southernmost *Barren Island*, I imagine it is meant to be placed to the southward of the northernmost, as I think it seems doubtful whether there are but one or two Islands. The Island of *Narcondam* bears N. by E. ½ E. 23 leagues distant, from *Barren Island* in lat. 13° 26′ N. and Long. 93° 30′ E. from Greenwich, both ascertained from very good observations. The Island *Narcondam* and *Barren Island* appear very different when seen at some distance; so that, independant of their latitudes, with a simple sketch of each Island a man could be at no loss readily to know the one Island from the other. *Narcondam* makes like a sugar loaf, quite flat at the top, and may be seen at least 18 leagues from the mast head, for we saw it 13 or 14 leagues from the poop pretty high out of water, the weather rather hazy; this distance may be depended upon as its calculated from the bearings and differences of latitude.

"*Barren Island* appears much longer, but not quite so high; the watermost ext, is the highest, and makes with a peak, descending to a low point to the eastward, although when you come near it, it seems of an equal height, with a peak at each end; it may be seen at least 15 or 16 leagues, for it was high out of the water when we saw it bearing N. by W. 12 or 13 leagues distant per calculation."

One Island, or two?

In explanation of Captain Taylor's surmise, whether one Barren Island, or two, existed, I may say that in various atlases of the eighteenth century[3] two small islands are marked, one nearly due north of the other, on a meridian some 50 miles east of (what appears to represent)

[1] *Cf.* Gough's observations. F. R. M.

[2] That reported by Gough and Justice? F. R. M.

[3] *e. g.* "Le Neptune Oriental on Routier général des Côtes des Indes Orientales," Paris, 1745 (*Isles Rases*). "Carte de L' Inde par le Sr. D'Anville, dated 1752, contained in the same author's "Géographie Ancienne Abrégée," 1769 (*Isles Rases*). "A New Directory for the East Indies" (based on Le Neptune), 6th edition, London, 1767 (Barren Islands). "The East India Pilot or Oriental Navigator," 2 charts dated respectively 1778 (Flat Islands and Barren Islands—both names given) and 1781, Flat Islands.

the South Andaman. The latitude of one varies from 11° 21′ to 11° 30′; that of the other from 11° 59′ to 12° 8′. In the French Atlases these are called the '*Iles Rases,*' while in some of the English they are called the 'Barren Islands' and in others the 'Flat Island.' However, one or two of these names came into use (possibly through some mistranslation from one language into another), the northern *Isle Rase,* as charted, agrees very fairly in position with Barren Island, and cannot be intended for anything else. What the southern *Isle Rase* was intended for I do not know. It was not meant for the rock east of Duncan's passage,[1] for in some Atlases, (*e.g.,* Le Neptune Oriental), the latter is marked *in addition to* the *Isles Rases,* in latitude 10° 55′ or 11° 0′.

Perhaps the most likely solution is that (like Narcondam, as previonsly mentioned) Barren Island was duplicated on the charts, through discrepant determinations of its position. But it is at least a possibility that, like Graham's Island, in the Mediterranean, the southern Isle may have been an ephemeral one, due to a volcanic eruption, chiefly of fragmentary ejecta. It is conceivable that, after it had been washed away by the sea, the last visible remnants were the rocks reported by Captain Sharrington, 5 or 6 leagues S. S. E. of Barren Island, and that even these subsequently disappeared, thus explaining Horsburgh's remark that Sharrington's account "is rendered doubtful, for no signs of a shoal-bank in the situation described have been discoverd for many years."[2]

Another possibility is that the temporary Island, and Sharrington's rocks, were S. S. W. of Barren Island (the S. S. E bearing given by Taylor being due to a not uncommon kind of clerical error). This would place them in the line joining Flat Rock, Barren Island, and Narcondam, and on the suppositional submarine ridge of Dr. Prain,[3] and would account, in another way to that suggested above, for the rocks not being re-discovered to the S. S. E., as well as for the statement of the Portuguese Captain. It would be useless, however, to pursue this speculation reared on such a slender basis.

I have made unsuccessful attempts, at the libraries mentioned, to discover the original of Captain Blair's report on the Andamans, part of which, relating to Barren Island, is quoted by Lieutenant Colebrooke in the Asiatic Researches. The following letter,[4] however, dated 19th April 1789, serves to supplement the above: "To the Right Hon'ble Charles Earl Cornwallis, K. G., Governor General, etc., in Council:—

Blair, 1789.

My Lord * * * * After examining Diligent Strait and the archipelago, I proceeded to Barren Island and found the volcano in a violent state of eruption, throwing out showers of red hot stones and immense volumes of smoke. There were two or three eruptions while I was close to the foot of the cone; several of the stones rolled down and bounded a good way past the foot of it. After a diligent search I could find nothing of sulphur or anything that answered the description of lava. * * * I have, &c. "Archibald Blair."

[1] The 'Flat Rock awash' of the Admiralty chart; that reported by Captain Justice.

[2] India Directory, 3rd edition, 1827, Vol. II, p. 37.

[3] See abstract of his memoir in the following bibliography.

[4] Bengal Political and Secret Consultations. Dated Fort William, the 21st August, 1789. India Office Records. The portions of the letter omitted relate to the Andaman Islands.

The preceding account is, in most respects, very similar to that in the report alluded to, and the chief interest lies in the final sentence. I have argued, on other grounds,[1] that the lava streams which now extend from the central cone westward towards the sea were emitted after Blair's visit; but his own statement, that after diligent search he could find nothing resembling lava, puts the question beyond discussion. It is scarcely conceivable that any one, however inexperienced in volcanic geology, could fail to recognize the true character of such typical streams at the first glance.[2] There are, however, still further proofs that the lava was emitted after Blair's time. From the points of issue the streams flowed down the slope of the cone, and their heads now constitute a portion of its surface, so that there have been no accretions to the cone since the occurrence in question. But it is shown, in the succeeding paragraphs, that the cone has greatly increased in bulk since 1789, and any lava emitted then, or previously, and solidified on its flanks, would now be deeply buried beneath the later products of eruption. I have previously stated,[3] that no fragmentary ejecta (scoriæ, &c.) have ever fallen, direct from the crater, on to the surface of the lava, which must, therefore, have been emitted after the last eruption of such material. In other words, the lava must be the latest volcanic product, and cannot, apparently, have been emitted earlier than 1804, the date of the last outburst of which we have any record. We have no reason to suppose that the different streams were emitted at considerable intervals, and the existence of the hot spring in 1832 shows that the southern stream, at least, had been poured forth before that date.[4] That Blair found no sulphur is very natural. The superficial deposits are entirely confined to the newer cone,[5] which was inaccessible to him, owing to the eruption. Even if he could have ascended it, he would have found none. The present deposits have been formed since the last eruption of scoriae, and therefore long after his visit, while the outburst he witnessed must have destroyed, or buried, any previously visible.

Captain Blair's landing on the island still remains the first, of which we have any record.

It is worthy of mention in connection with Blair's visit, that Test's "view of the volcano on Barren Island, bearing east, about one mile off"[6] taken the day before Blair landed, gives the means of arriving at an approximation to the height of the newer cone at that time. The sketch represents the summit of the cone as rising very slightly above the sky line of the old crater rim behind it, and a careful comparison of corresponding points in the sketch, and in Hobday's map of 1884, shows that the artist, the summit of the cone, and the eminence on the old crater rim which Hobday marked as 1060 feet, in height, were in a line; and likewise shows that the eminence in question was concealed, and only just concealed, by the summit of the

[1] Mem. G. S. I., Vol. XXI, p. 271.

[2] There was of course lava in abundance visible to Capt. Blair, at a distance, where it outcrops, interbedded with scoriae, on the scarped walls of the ancient crater. But its petrological character in such position would be far from self-evident to a non-geologist.

[3] Mem. G. S. I., Vol. XXI, p. 271.

[4] *Ibid* p. 274.

[5] There may possibly exist buried deposits amongst the rocks of both the ancient and the newer cone.

[6] A water colour sketch measuring 16½ inches × 6: British Museum library, Press mark K. 116, 31, *Vide* Mem. G. S. I. Vol. XXI, p. 262, the illustration accompanying this paper is a photographic reproduction on the scale of one-half.

cone[1]: in other words, the eminence and the cone subtended almost exactly the same angle, their respective distances from the point of view, and the height of the eminence,[2] being obtained from the map, give the height of the cone as exactly 800 feet, assuming the two angles involved to be identical, and that Test estimated his distance from the shore correctly. I do not think any probable difference in the angles would make a difference of more than 20 or 30 feet in the height, while an error of a quarter of a mile in the estimated distance, one way or the other, would make a difference of about 30ft. The errors due to these two sources if they exist, may partially, or entirely, neutralize each other; but even if they are both of the same sign, the total error is probably well under 100 ft., and is almost certainly not over this amount. While, therefore, it may be taken as almost beyond question, that the height of the cone was between 700 and 900 ft., it is much more likely that it was between 750 and 850 than outside these limits, and the most probable altitude is about 800[3].

Lieutenant Wales' sketch, as reproduced in the Asiatic Researches (Vol. IV) is on a smaller scale than Test's, and shows marks of less careful elaboration; but the height calculated from it agrees very fairly with the above, giving the most probable elevation as between 800 and 830 ft., the lower figures being the more likely.

Corroborative evidence of a considerable increase in the size of the cone is afforded by a large protuberance, represented in Test's sketch on the lower part of the north-western slope. This was quite obliterated in 1884, owing, doubtless, to its having been buried beneath the ejecta that have been emitted since Test used his brush.

Supposing the true height to have been 800 ft., the cone, which is now 1015 must have just doubled in bulk between the time of Blair's visit and 1857, since which date we know that there has not been any eruption, a suggestive conclusion in regard to the period of time during which the entire pile may have been heaped up.[4]

Test, like others,[5] over-estimated the slope of the newer cone, where, as is mostly the case, the sides are composed of fragmentary ejecta, the declivity is almost perfectly uniform, at an angle of about 32 degrees, except near the base, where the inclination gradually diminishes in a graceful curve.[6]

[1] That is to say if the cone were away, the sky-line of the crater rim would be seen to rise towards, and culminate in the eminence. As the sky line at each side is but slightly lower than the summit of the cone (in the sketch), the eminence must be, as nearly as possible, equally high.

[2] Test's sketch gives no reason to suppose that the height of the eminence is different now to what it was in 1789, although it is perhaps a few feet more, owing to accumulations of scoriae due to the eruptions since then. Any alteration due to movement of the crater walls (had such occurred) would probably be in the direction of subsidence, and would tend to reduce the calculated height of the newer cone.

[3] According to Blair's account, as quoted by Colebrooke, the elevation was "1,800 feet nearly"; a manifest clerical error. Were the figures he actually gave 800?

[4] *Cf.* Mem. G. S. I., Vol. XXI, p. 265.

[5] As pointed out by Dr. Ball (Records, G. S. I., Vol. VI, p. 82).

[6] See illustration in Mem. G. S. I., Vol. XXI, p. 251.

The following extract from the log of the Ship 'Worcester,'[1] commanded by Captain Hall, adds one more to the recorded eruptions towards the close of the last century:—

Hall, 1795.

"Sunday, 20th December, 1795. At 10 A.M. the Commodore made the signal for seeing the land. Saw a long Island higher at the westward end sloping gently to the eastward N. W. ½ W. 14 or 15 leagues off deck. At noon it bore from N. W. to N. W. ½ W. take it for Barren or Monday Island. In the centre a smoke arises and has the appearance of a volcano. Its Lat. by the bearings is 12° 22′ N, and Long. by my chron. No. 1, 93° 54′ E. Greenwich × × × ×.

"Monday, 21st × × × ×. At 6 A.M. it bore S. ½ W. about 10 leagues and Narcondam (both from the deck) N. N. E. ¾ E. about 12 leagues. It was astonishing the repeated columns of black smoke which were sent up. There appeared no hill (as the whole Island is nearly a plain surface gently sloping to the eastward as mentioned in yesterday's log) but the smoke was from the other side of the ridge or on the eastern side."

Any one unacquainted with the true topography of the Island, and viewing it from a distance of several leagues, might easily suppose it to have a nearly plain surface, or to form a ridge. Captain Hall's remark that the Island is "higher at the westward end sloping gently to the eastward" agrees with Captain Taylor's that "the westernmost extremity is the highest, and makes with a peak descending to a low point to the eastward." But this appearance is evidently a deceptive one, as Captain Hobday's map shows that the volcano is highest towards the south-east, and we have evidence, in Test's sketch of the Island in 1789,[2] that, as far as the ancient cone is concerned, the outlines then were practically identical with the present ones. 114502

The volcano was again in eruption at the end of January 1804, when H. M. S. "Caroline" passed the Island. The log[3] contains the following entry on the 31st—"Several eruptions of fire from the volcano on Barren Island during the night." This outburst (as pointed out by Dr. V. Ball[4]) is also mentioned, by one of the officers, in an "account of a voyage to India and China, etc., in H. M. S. "Caroline."[5] His remarks are given in the following table.

Cason, 1804.

Not one of the observers before Colebrooke (1787) record any appearance of smoke rising from the Island, or make any remark indicative of their being aware of its volcanic nature, from which it may not unreasonably be assumed that, when they saw the volcano, it was quiescent or at most giving off a little steam.[6] It seems difficult to imagine that while the bearings, etc., of the Island were duly recorded in the log, an eruption, if witnessed, should be absolutely ignored, and we may, perhaps, further surmise that the volcano was in the same condition when seen by the unknown

Probable condition of volcano in 18th century.

[1] India Office Records.

[2] *Vide* accompanying reproduction and Mem. G. S. I., Vol. XXI, p. 262.

[3] Public Record Office.

[4] *Geological Magazine*, 1888, p. 404.

[5] Phillip's Voyages and Travels, Vol. V.

[6] Colebrooke saw smoke when he was 7 leagues off the Island, and Hall (1795) when 10 leagues, or more. Such indeed would be easily visible when the Island itself was below the horizon.

observers who first applied the names 'Monday' and 'Barren' Island; at dates we are unacquainted with, but which seem not improbably to lie between 1708, when Stretham charted the Island as an anonymous one, and 1748, before which time both names appear to have been in use.[1] Had the volcano been in eruption when the observers in question saw it, it does not seem unlikely that they would have given names suggested by the remarkable phenomenon of which they were spectators.[2]

Assuming, however, that the volcano was quiescent at the dates previously given, it would still be unsafe to argue very confidently as to its general condition in the eighteenth century, as, during the intervals of which nothing is known, many eruptions may have occurred for ought we can assert to the contrary. But, at the same time, the fact that on every one of the six dates included in the following records, between 1787 and 1804, the volcano was very active, and mostly in eruption, while on each of the (three or) four dates between 1748 and 1780 it appears to have been quiescent, can hardly be attributed entirely to chance. Hence it can scarcely be doubted that several outbursts during the two decades following 1785, have passed unnoticed, while we shall, perhaps, not greatly err if we regard the preceding four decades as a period of at least comparative, and possibly total, tranquillity. There is also, as we have seen, some very slight ground for surmising that this tranquillity may have extended back to the early part of the century. Of antecedent ages we know nothing from direct observation unless the suggestion thrown out in connection with Linschoten's map may be taken as one very faint hint.

Tabular abstract.

In conclusion, it may be convenient to add a revised edition of the tabular abstracts given in my memoir on the volcano,[3] incorporating the preceding records, and also the observations that have been made since 1884.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
1595 .	The Island appears to have been known at this time, but there is no indication of its volcanic nature having been recognised.	......	Maps in Van Linschoten's itinerario.
7th Dec. 1708.	Dormant	......	Captain Gough; log of ship "Stretham."
28th & 29th Oct. 1748 .	Dormant	......	Captain Cheyne; log of ship "Lapwing."
1758 .	Dormant?	......	Captain Mills, of ship "Drake." "Memoir of a chart of the Indian Ocean, 1787, p. 37, in Dalrymple's Nautical Memoirs, Vol. I.

[1] *Cf.* Notice of Cheyne's observations, and foot-note mentioning "Le Neptune Oriental" etc.

[2] *Cf.*, however, foot-note in the next paper, on the possible origin of the name 'Barren.'

[3] Mem. G. S. I., Vol. XXI, p. 272 and 275.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
2nd Nov. 1771 .	Dormant	......	Captain Justice, of ship 'Union' M. S. Bengal Public consultations, and Memoir of a chart of the Indian Ocean (op. cit.), p. 36.
13th & 15th Jan. 1780 .	Dormant	......	Captain Taylor, of ship "Ceres," Dalrymple's Nautical Memoirs, Vol. II.
12th May 1787 .	"Column of smoke ascending from the summit" was seen from a distance of 7 leagues. No nearer approach to the Island was made.	......	Lieutenant Colebroke, Asiatic Researches, Vol. IV. p. 397.
24th March, 1789.	"The volcano was in a violent state of eruption, bursting out immense volumes of smoke, and frequently showers of red hot stones. Some were of a size to weigh three or four tons, and had been thrown some hundred yards past the foot of the cone. There were two or three eruptions, while we were close to it; several of the red hot stones rolled down the sides of the cone, and bounded a considerable way beyond us." The newer cone was probably about 800ft. high.	No mention of the spring. Blair was the first who landed on the island, as far as is known.	Capt. Blair, quoted by Colebrooke; *loc. cit.* Letter from Capt. Blair, dated 19th April, 1789. Test's sketch of 23rd March, 1789.
1791 .	"A quantity of very white smoke close to the crater."	......	India Directory, by J. Horsburgh, 3rd edit. (1827), Vol. II, p. 37.
20th and 21st Dec., 1795.	On 20th smoke observed: on 21st, "It was astonishing the repeated columns of black smoke which were sent up."	......	Capt. Hall; log of ship "Worcester."
November, 1803.	"Exploded regularly every 10 minutes, projecting each time a column of black smoke perpendicularly to a great height; and in the night, a fire of considerable size continued to burn on the east side of the crater."	......	Horsburgh; *loc. cit.*
29th—31st Jan., 1804.	29th. Volcano "was burning very fiercely, the eruptions taking place every eight or ten minutes, with a hollow rumbling noise. * * * We passed within a mile of it, and as the winds were trifling we observed the eruptions for three days and nights successively." 31st. Several eruptions of fire during the night. The recent lava streams appear to have been emitted not earlier than this date.	......	Officer of H. M. S. "Caroline"; Phillip's Voyages and Travels, Vol. V. Log of the "Caroline."

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
March, 1832	"Large volumes of thin white smoke kept continually issuing" from the summit. The southern lava stream was emitted before this date, as evidenced by the existence of the hot spring. Probably the other recent streams had also been poured forth	"On approaching to within a hundred yards of the shore, we were suddenly assailed by hot puffs of wind, and on dipping our fingers into the water, were surprised to find it as hot almost as if it had been boiling. The stones on shore, and the rocks exposed by the ebbing of the tide, were smoking and hissing, and the water was bubbling all round them."	Commander of a ship; Journal, Asiatic Society of Bengal. Vol. I, p. 129.
April, 1843	From the summit of the cone "a clear and full stream of transparent vapour issued, so transparent that it was not perceptible from the sea."		Captain Miller; Calcutta Journal of Natural History, Vol. III, p. 423.
1852	Very active.		"Bombay Times," July, 1852.
18th Dec., 1857.	"Some smoke was seen occasionally to issue from the slope of the cone" a little way below the summit. The date of the last eruption is unknown, but the unchanged condition of the crater shows that there was none between December 1857 and April 1891.	Temperature "too high to be borne by the hand, the mercury in the only thermometer in our possession rising immediately to 140°—its limit."	Dr Playfair; Selec. Rec. Govt. of India (Home Department), No. XXV, p. 123. Mem. G. S. I, Vol. XXI, p. 268. Dr. Prain; see below.
Ibid.		'A natural boiling spring."	Dr. Mouat; Researches amongst the Andaman Islanders.
19th March, 1858	"Clouds of hot watery vapour," with a sulphurous smell, issued from cracks near the summit, on the northern and southern edges of the crater. The recent lava streams were (superficially) "cold."	"The water, where escaping from the rock, must have been nearly at the boiling point."	Dr. Liebig; Zeitschrift der Deutsch Geol. Gesellschaft, Vol. X, p. 299. Selec. Rec. Govt. of India, No. XXV. p. 126. Also in Jour. As. Soc. Bengal, Vol. XXIX, p. 1; and in Mouat's Researches.
1862	Sulphurous vapours issuing along the edge of the crater.	"Scalding hot"	Rev. C. Parish; Proceedings, Roy. Geog. Soc., Vol. VI, p. 217.
19th April 1866	A whitish vapour was evolved from several deep fissures near the summit.	158° to 163° F.	Andaman Committee; Proceedings, As. Soc. Bengal, Oct. 1866, p. 215.
March 1873	From the highest point on the northern edge of the crater a thin column of white vapour, and sulphurous fumes were slowly poured forth.	130	Prof. V. Ball; Records G. S. I., Vol. VI, p. 88.

Date.	Condition of volcano.	Temperature of hot springs.	Authority.
Feb. 1884 .	Superheated steam, with sulphurous vapour issued rather copiously from the solfatara on the north side of the crater, the column, as it rose into the air, being visible from the landing-place, or even some distance out at sea. Steam, in smaller quantity, issued from some other spots also.	106° to 116° . . .	F. R. Mallet; Mem. G. S. I., Vol. XXI, p. 273, 274.
2°th April 1886 .	"From the ship the thin column of steam (from the central cone) could be barely seen at 3 miles distance."	110°	Capt. Carpenter, R. N., H. M. I. M.S. 'Investigator'; Records, G. S. I., Vol. XX, p. 48 Mr. Daley, of Investigator; Ex. Cit.
April 1891 .	Some steam issued from the crater but considerably less than in 1886; it was not visible from the sea, or even from the landing-place. New crusts of sulphur, from ¾ to 2½ inches thick, had been formed at the solfataras since February 1884.	102° to 106°. . . .	Dr. Prain; Proceedings, As. Soc., Bengal, May, 1891, p. 84.
1894 .	"The Volcano is apparently entering on a period of renewed activity." This somewhat vague statement does not seem to have been corroborated.	......	Port Blair correspondent of the Allahabad 'Pioneer'; quoted in 'Nature', 7th June 1894, p. 131.

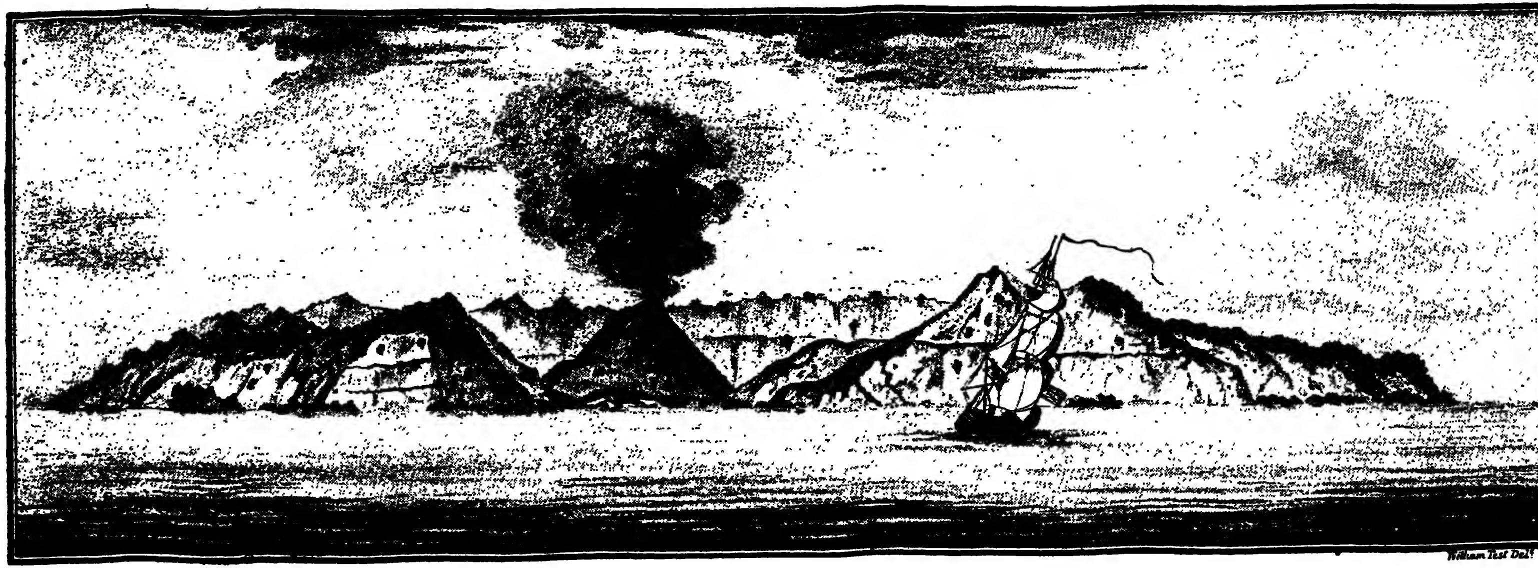
Bibliography *of* Barren Island *and* Narcondam, *from* 1884 *to* 1894; *with some remarks by* F. R. Mallet, F.G.S., *late Superintendent, Geological Survey of India.*

The Bibliography of the Islands up to 1884 may be gathered from Dr. V. Ball's paper in an earlier volume of the records,[1] from my report of 1884, and from the preceding pages. The following papers have appeared during the last ten years, but I am not prepared to say that the list is complete, as there may be other references to the Islands which have escaped my notice.

1. "Volcano of Barren Island in the Bay of Bengal": American Journal of Science, Vol. XXXI (1886), p. 394. A critical notice of my Memoir, by Professor J. D. Dana.[2]

[1] Vol. VI (1873), p. 81. Republished in the Geological Magazine 1879, p. 16.

[2] It is, perhaps, worth mentioning here, that the statement, alluded to by Prof. Dana,



A VIEW of the VOLCANO on BARREN ISLAND, Bearing East, about one Mile off: Taken on Board the Honble Company's Snow Viper, March 23d 1789.

The writer discusses the way in which the upper part of the cone of a volcano is destroyed, and a great crater, like the ancient one of Barren Island, produced. He holds that, during a paroxysmal eruption, the portion of the cone in question is not blown away peacemeal, but that the walls of the crater are undermined by the melted lava, and sink down in consequence into the abyss beneath. "Finally in the catastrophic eruption when the force from the rising vapours and from other conditions becomes greater than the mountain can withstand—a point often abruptly reached—the sides break and one or more fissures let out the liquid lavas. However explosive the action, the solid rock of the summit of the cone, while it may be more or less removed by the forces engaged, instead of being projected over the outer slopes, sinks down into the abyss so made. Thus a volcanic cone under the most formidable of explosive eruptions may lose its head, but if so, it is by swallowing it, or simply by a collapse. The same is the process in quiet Kilauea, the solid lavas of the borders of the fiery region sink because the discharge of the liquid rock makes a void beneath them."

A subsidence of the lava in Kilauea, and concomitant collapse of the crater walls into the fiery lake, which took place last July, was observed by Mr. L. A. Thurston, apparently the first actual eye-witness of such an occurrence. His graphic account[1] is in complete accordance with Professor Dana's view. But Kilauea is a volcano of an unusual type, and widely different from Vesuvius or Barren Island. However large a share engulphment may have in producing great craters in volcanoes of the latter type, that it is the sole agent and that ejection of the material of the crater wall, in a more or less communicated state (produced mechanically, or by fusion), never plays a prominent part in the affair, is an opinion widely at variance with that held by most volcanologists.

2. "On soundings recently taken off Barren Island and Narcondam by Commander A. Carpenter, R.N., H.M.I.M.S., 'Investigator,' the officer in charge of the Marine Survey of India." By F. R. Mallet. Records, Geological Survey of India, Vol. XX of 1887, p. 46.

The results of soundings, taken in May 1886, are given with some remarks thereon. The depths measured within four miles of Barren Island range up to 855 fathoms, aud those within a league of Narcondam up to 652. Sections of the islands are appended, based on Captain Carpenter's soundings and Captain Hobday's maps.

3. "The volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, M.A., F.R.S.. F.G.S, Geological Magazine, 1888, p. 404.

Mainly a notice of the chief results of the survey by Captain Hobday and myself in 1884, with some remarks thereon. Refers to the eruption of January 1804, seen by an officer of H. M. S. 'Caroline' (*vide* preceding paper.)

4. "The Andamans and Andamanese." By Colonel T. Cadell, V. C., Scottish Geographical Magazine, February 1889, p. 56.

Includes a brief account of Barren Island, written partly from personal observation, partly from previous descriptions.

that the cone "has been entirely built up during the last 1800 years," is not merely in connection with Barren Island, but a quotation from Professor Judds' 'Volcanoes,' in reference to Vesuvius.

[1] American Journal of Science, Vol. XLVIII (1894), p. 338.

5. "On the present condition of Barren Island." By D. Prain, M B., Proceedings, Asiatic Society of Bengal, May, 1891, p. 84.

Gives some of the geological results of a visit in April 1891—An abstract of these is included in the preceding table.

6. "Remarks on the Fauna of Narcondam and Barren Island." By D. Prain, M. B., Proceedings, Asiatic Society of Bengal, April, 1892, p. 109.

The paper is almost entirely geological, but, at the end, contains some remarks on the relation between the geology and biology. The author recognises that the islands are, and always have been, oceanic. "The present physical conditions in Narcondam appear, moreover, to be very ancient; there is no trace of a crater at the top of its peak which rises 2,330 feet above the level of the Andaman Sea, and the whole island is clad with a dense jungle much richer in species than the forest on Barren Island is. But though the present biological features of Barren Island are of a much more modern aspect, it is not necessary to consider that island as really less ancient than Narcondam. The topography of its outer cone, combined with the historical fact of recent activity on the part of the volcano, points to the possibility of some catastrophe similar to that which devastated Krakatau, having once happened in Barren Island, and if this has been the case it would follow that the island must have required, even if previously covered with vegetation, to be stocked *de novo* with vegetable and animal life. Still, granting that the present fauna and flora of Barren Island are of more recent introduction than those of Narcondam, the fact remains that we must look upon every species present, even in the island with the older biological features, as an immigrant one."

The only catastrophic outburst of which evidence still remains, and that, I presume, referred to by Dr. Prain is the one which probably effected the truncation of the ancient cone, and originated the crater now over a mile in diameter. From a biological point of view, as well as from a geological one, therefore, the period at which this change took place is of some interest. It is impossible to form any definite estimate of the time involved, but there is reason to believe that the event occurred at a very remote epoch. The deep gorges which score the external slopes of the volcano, point to long-continued denudation, which shows no apparent signs of having been interfered with by lava flows from the ancient cone. But still more suggestive is the gorge which debouches into the crater S. S. E. from the hot spring, unless, as is conceivable, this ravine, drained into a great east and west "barranco," which may possibly have existed prior to the origination of the present amphitheatre, the ravine must, apparently, have been excavated since the amphitheatre was formed. That is to say, since the event in question, some hundreds of feet of alternating scoriæ and lava beds have been cut through near the mouth of the gorge, where it is deepest. The stream, too, which has done the work, owing to its small size, and the porous nature of the rocks, is under the disadvantage of flowing only in the rainy season, and perhaps not constantly even then.[1]

The time indicated above is so immense, compared to that during which the

[1] The water, for some distance seaward from the breach, appears to have been somewhat reduced in depth, owing, doubtless, to the material swept into the sea from the gorge just mentioned, and from the amphitheatre generally, combined with the submarine portion of the recent lava (cf. sections in Vol. XX, p. 48.)

materials of the present cone may have been piled up,[1] as to suggest that the paroxysmal eruption, supposed to have truncated the ancient cone, was perhaps followed by a long interval of quiescence, before the building up of a newer cone was begun, and several such may have arisen, and been destroyed, before the present one was reared. In comparison with the antiquity of the older cone, the existence of the present one may date from almost yesterday. Or, to put it differently, while the duration of the one must be measured by geological time, it is possible for the other to have originated during an even historically recent period.[2]

Granting that life was extinguished by the catastrophe just alluded to, as suggested by Dr. Prain, the question may be raised whether the present fauna and flora date from that epoch, or from a still later destruction due to some overwhelming shower of ejecta. I am not competent to express any opinion as to the time required to re-stock the island: but looking simply to the probable intensity of the eruptions in comparatively recent times, *i.e.*, since the present cone was commenced. I see no cogent ground for regarding a total destruction of the island life as very probable. There is no reason for assuming that the earlier outbursts from the present cone were on an essentially grander scale than the later ones; and I have shown in the preceding paper that a large fraction, perhaps half the bulk, of the cone[3] has been added by the eruptions that have occurred since 1789. But Test's sketch shows that the exterior slopes of the island were well-wooded at that date, and that the arboreal vegetation was not subsequently destroyed may be inferred from Capt. Miller's describing the outer slopes as well-wooded in 1843, and from the fact that no remains of lifeless forest have ever been noticed.[4] At the same time it can scarcely be doubted that considerable damage has been done to the vegetation, perhaps on many occasions. But such damage would be much more severe in the amphitheatre than on the external declivities.[5]

7. "Note on the occurrence of quartz in an Indian basic volcanic rock." By T. H. Holland, A. R. C. S., Bulletin of the Microscopical Society of Calcutta, Vol. II, No. 6 (1893), p. 3.

The rock in question is from Narcondam, and described by the author as a basaltic andesite, the quartz being regarded as of volcanic, not extraneous origin.

[1] Cf. remarks in preceding paper in connection with Blain's visit, and Mem. G. S. I., Vol. XXI, p. 265.

[2] If we may regard the relative bulks of the two cones as giving some sort of rude illustration of the orders of magnitude of the two periods involved, we find that while the newer cone is about 1,000 ft. in altitude, the ancient one was probably once 8,000 or 10,000 from the sea floor (Vol. XX, p. 46), requiring, perhaps, 500 or 1,000 times as much material.

[3] That is to say, the cone above sea-level, and not including the mass of material which was doubtless required to fill up the ancient crater to that level.

[4] *Cf.* Memoirs, G. S. I., Vol. XXI, p. 262.

[5] If the view expressed in the above paragraph be correct, the island can scarcely have acquired its name from any striking barrenness of the now well-wooded outer slopes. Although I believe the name was most probably given on account of the barrenness of the newer cone, and parts of the amphitheatre, it has occurred to me, as a possibility, that, as the word Narcondam is of eastern origin, so 'Barren' may be an English corruption of some name applied by the Asiatic sailors of the region in question. The Hindustani *barna*, to burn, *barat*, burning, and *barkm jon*, a volcano, for instance, are somewhat suggestive. Some reference to the island may yet be discovered which will elucidate the origin of the name.

8. "On the Volcanoes and Hot Springs of India, and the Folklore connected therewith." By V. Ball, C.B., LL.D., F.R.S. Proceedings of the Royal Irish Academy, 1893, p. 151.

Refers, *inter alia,* to Barren Island and Narcondam.

9. "The Volcanoes of Barren Island and Narcondam in the Bay of Bengal." By V. Ball, C.B., LL.D., F.R.S., Geological Magazine, 1893, p. 289.

Descriptive of a model of Barren Island, constructed under the author's superintendence, and based chiefly on the data supplied by Capt. Hobday's map. A bird's eye photographic view of the model is given, in which the sea surrounding the island is also represented. The paper concludes with some notes on the fauna of the islands.

10. "On the flora of Narcondam and Barren Island." By D. Prain, M.B. Journal of the Asiatic Society of Bengal, Vol. LXII (1893), Part II, p. 39.

A memoir divided into three sections. The first, or 'Introductory sketch,' commences with some remarks on the hydrography of the Bay of Bengal (in its wider sense), for the portion of which, enclosed by the Andaman and Nicobar Islands, Alcock's name of 'Andaman Sea' is adopted. Carpenter's soundings round the two volcanoes[1] are reproduced, with some additions: the configuration of each island is described, and a summary account of its vegetation given,[2] the soundings round flat rock[3] are added, which the author very plausibly suggests is probably of Volcanic origin. The bathymetry of the Andaman Sea is reviewed, and the question of the northern prolongation of the line of volcanoes through the Sunda Islands, Java, Sumatra, Barren Island, and Narcondam is discussed. This the author, following Dr. W. T. Blanford, considers, is to be found in the extinct volcano of Puppa, in Upper Burma, and that near Momein, in Yunnan, which, as he remarks, lie in common with the volcanoes of the Andaman Sea, to the eastward of, and rudely parallel to, the line of elevation represented by the Andaman Islands and the Arrakan Yoma. Evidence is likewise adduced to show that Flat Rock, Barren Island, and Narcondam are not isolated peaks rising from the sea-floor, but are situated along a submarine ridge.

The second portion of the Memoir is an annotated list of the plants found on the islands, and the third discusses the "Nature and origin of the Flora." 174 species were discovered, of which 138 occur on Narcondam and 88 on Barren Island, only 52 being common to both volcanoes. In conclusion the probable mode of introduction—by the sea, by winds, by birds, or by man—is taken into consideration. Appended are two bathymetric charts of the area surrounding the Andaman Islands.

An abstract of the Memoir was given in the Geographical Journal for March 1894, p 234.

[1] Records, G S. I., Vol XX, p. 46,

[2] With reference to the foot-notes in Dr. Prain's Memoir, at pages 45, 49, 56, and 77, in connection with the occurrence of cocoanut trees on the islands, I may say that Mr. Wight, 2nd Officer of the I. M. S. 'Celerity,' and I, landed at Coco Bay in Narcondam, and saw the trees in question there. We found a large log of teak, with hewn ends, on the beach, which may be presumed to have drifted from the mouth of some Burman river; a suggestive fact with reference to the origin of the cocoanuts from which the trees have sprung, and of other species of plants also. We, and several other members of the expedition, also landed at Anchorage Bay, in Barren Island, the surf at the time being comparatively slight.

[3] The rock east of Duncan's passage, alluded to more than once in the preceding paper.

ERRATA.

RECORDS, GEOLOGICAL SURVEY OF INDIA, Vol. XXVIII, part 1, pages 22—38.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1895. May

On the importance of the Cretaceous Rocks *of* Southern India *in estimating the geographical conditions during* later cretaceous times[1]; by FRANZ KOSSMAT.

OUR knowledge of the extra-European cretaceous rocks, more especially those of the Indo-Pacific area, has, in the course of the last few years, made enormous strides, and we shall soon be in a position to form a clear conception of the zoological and geographical conditions of that period. The cretaceous rocks of Southern India, which formerly, in spite of their great wealth of fossils, were accorded little more than the importance of a mere local development, are now coming more and more to the front, since the elements of their fauna have been discovered in a great series of cretaceous beds, while Neumayr[2] in his "Erdgeschichte" selects them as the type of the Pacific cretaceous area.

Nevertheless, since the completion of Stoliczka's[3] great monograph on the cretaceous Fauna of Southern India, neither our palæontological nor yet our stratigraphical knowledge of this important area has been appreciably extended, although of late years, the urgent necessity of revision—more especially as regards the cephalopods—has repeatedly asserted itself. Opportunity for such research is now offered by the new collection made in the Trichinopoly district during the winter of 1892-93, and part of the summer of 1893, by Dr. H. Warth, of the Geological Survey of India, and sent by him to Prof. Waagen, at Vienna, who has entrusted this interesting and important task to me. Our material for this research is now practically complete, owing to the addition to it of a large number of Stoliczka's original specimens, which have been sent to us for re-examination by Dr. King, the late Director of the Geological Survey of India.

The results, as regards palæontology, will shortly be published in the "Beiträge zur Palæontologie und Geologie" (edited by Professor W. Waagen), to which I hope to add a detailed account of those relating to the stratigraphical and zoological conditions. I will, therefore, at present restrict myself to a few general conclusions.

Owing to their peculiarly favourable position between the chalk of the Altantic and that of the Pacific area, the cretaceous rocks of Southern India are eminently adapted to serve as a starting-point for observations on the zoo-geographica condi-

1 Translation of paper published in the Jahrb k.k. Geol. Reichsanst 1894, Vol. 44, pt. 3.

2 M. Neumayr: Erdgeschichte, Vol. II, p. 390.

3 F. Stoliczka: Cretaceous Fauna of Southern India (Palæontologia Indic , 4 Vol. Calcutta, 1865-1873.

tions of later cretaceous times. Their fauna combines in itself the elements both of the eastern and of the western hemisphere, and thus serves as a connecting link between the two.

On the subject of the rich endemic fauna of the Indian cretaceous rocks, and the interesting survivors from older beds, which play such an important part in them, it would not be advisable to speak here.

The cretaceous rocks of Southern India fall into two main divisions: *viz*., the larger Trichinopoly district, and the smaller and more northerly Pondicherry area—both south of Madras, and part of the so-called Coromandel coast, on the eastern side of the Indian peninsula.

During the geological survey of the Trichinopoly district,[1] it was found that a large number of the fossils collected bore a striking resemblance to forms occurring in Central Europe, and Stoliczka, in his work on the fauna, was thereby induced to unite no small proportion of the species — among the cephalopods no less than 25 per cent. — directly with European forms. Although on re-examination several of these identifications have proved erroneous, the affinities to the European fauna are still remarkable, more especially if we have regard not only to identical, but also to closely allied, forms. Extremely important also, and of great service in estimating the age of the beds of this system, is the fact that the succession of individual forms is to a great extent identical with that seen in Europe—a fact not fully appreciated by earlier observers.[2]

At the base of the Utatur group, just as in Europe at the base of the cenomanian, occur *Schlœnbachia inflata* Sow. and several allied species, *Hamites armatus* Sow, *Turrilites bergeri* Brongn., etc. In higher beds we meet with an extraordinarily rich *Acanthoceras* fauna, of the type of *Ac. rhotomagense* Brong., while a large number of other well-marked forms, such as *Turrilites costatus* Brong., and *Alectryonia carinata* Lam. identify this horizon as the equivalent of the middle and upper cenomanian. The uppermost beds of the *Utatur group* I consider to be of lower turonian age, the typical *Acanthoceras* element having disappeared, and being replaced by Ammonites related to the European *Mammites nodosoides* (*Amm. conciliatus* Stol.) and to the well-marked *Inoceramus labiatus* Schloth. of the turonian.

The Trichinopoly group abounds in excellent specimens of Gastropods and Bivalves, which are, however, of little assistance in the determination of the horizons. Ammonites of central-European character are somewhat scarce, some very well-marked forms, however, being present. In the lower Trichinopoly group *Am. serrato-carinatus* Stol. (allied to *Am. bravaisianus* Orb.) represents the turonian form *Prionocyclus*, while with it are associated typical forms of the important group of *Pachydiscus peramplus* Mant. The higher beds of the Trichinopoly group are marked as lower senonian by their gastropods and bivalves, but more especially by a *Schlœnbachia* of the *tricarinata* type and a *Placenticeras* extending from the group of *P. placenta* Mort.

In the Ariyalur group, the most important cephalopods are the upper senonian

[1] H. F. Blanford: On the cretaceous and other Rocks of the South Arcot and Trichinopoly Districts; Madras (Mem. Geol. Surv. India. Vol. IV, pt. I.) Calcutta 1865.

[2] F. Stoliczka merely remarks that the Utatur group (the oldest of the three lower divisions) may be broadly compared to the cenomanian, the Trichinopoly group to the turonian and the Ariyalur to the senonian. (loc. cit. vol. IV, p. II.)

Pachydiscus and *Baculites*. In the highest division at Ninnyur, which ought preferably to be separated from the rest of the group,[1] the ammonites have disappeared while *Nautilus danicus* Schloth., and numerous gastropods and bivalves of more recent type, mark these beds as the boundary between the cretaceous and tertiary rocks.

To the Ariyalur group also I refer the great fauna of Pondicherry, which was considered by E. Forbes[2] to be of lower cretaceous age. Stoliczka, following Blanford,[3] endeavoured to distinguish, by their fauna, two horizons, the older of which, the Valudayur group, he characterised as cenomanian (Utatur group), while the other he considered to be of the same age as the Ariyalur group. In the course of time, however, it became evident that many of the fossils of the Valudayur group occurred in the Ariyalur beds of the Trichinopoly district, and Stoliczka was consequently much puzzled as to the true age of the Valudayur group, nor did he ever arrive at a solution of the difficulty.

During the past summer, I had the opportunity of studying Forbes' original specimens of the Pondicherry fauna, and came to the conclusion that all his specimens of ammonites from that district were derived from the hard brownish or bluish "Lumachelle" (fire-marble) and plainly from one single horizon. This may be proved by the similarity in the association of the forms and the mutual resemblance of the specimens. This horizon is Blanford's Valudayur group. In the abundant ammonite fauna of this series, we find not a single representative of the typical cenomanian fauna, so familiar in the Utatur group; we find no *Schlœnbachia*, no *Acanthoceras*, no *Turrilites* while on the other hand we have the typical senonian *Pachydiscus*, a true *Sphenodiscus* (*A. siva* Forb.) very closely allied to the senonian *S. lenticularis*, as well as innumerable *Baculites vagina* and other ammonites. That the Valudayur group is in reality a development of the Ariyalur group, differing from it somewhat in lithological characters, may be proved by the following facts: (1) many of its most important fossils, such as *Pachydiscus egertonianus*, *Am.* (*n.g.*) *brahma*, *Baculites vagina*, etc., occur also in the Ariyalur group, whereas (2) the small number of species, which it contains in common with the Utatur group, has, on re-examination, been reduced to a few doubtful cases; and lastly, the gastropods and bivalves associated with the ammonites have considerable affinities to those of the Ariyalur, but none to those of the Utatur group.[4] Even in the Trichinopoly district the Ariyalur group overlaps the older cretaceous beds, which, further north, disappear beneath it, both in the S. Arcot district and also, as has now been proved, in the Pondicherry area. During the winter of 1893-1894, Dr. H. Warth undertook a revision of the survey of the Pondicherry district, and the fossils collected by him are now in course of transmission to Vienna, and will, it is hoped, throw much light on the question of the age of these rocks.

Lithologically, the upper beds exposed in Pondicherry (white sands and conglomerates) which were included by Blanford and Stoliczka in the Ariyalur group, differ from the Valudayur beds; nor could I find a single ammonite in

[1] This suggestion is also made by H. Leveillé in his small work: Geologie de l' Inde Francaise (Bull. Soc. Geol. France, 1890. t. XVIII) p. 144 ff.

[2] E. Forbes: Cretaceous fossils of Southern India (Transaction of the Geol. Soc. of London, II Ser., Vol. VII, London 1845-1856, Art. V. p. 165).

[3] H. F. Blanford. l. c., p. 151 ff.

[4] A. d'Orbigny considers the Pondicherry beds to be of senonian age. (Prodrôme de Paleontologie II., Paris, 1850, pp. 213, 215, 216, etc.)

Forbes' collection, while, on the other hand, Blanford discovered a *Nautilus danicus*, of the species occurring in the Ninnyur beds of the Trichinopoly district.

The question as to the connection between the cretaceous sea of southern India and that of Europe has already been repeatedly discussed. The careful examination of the Narbada cretaceous fauna, in which, after a cursory determination, Bose [1] believed that he had discovered Trichinopoly species, has proved its entire dissimilarity to that of the Trichinopoly-Pondicherry districts, while its echinodermata [2] have been shown to bear a striking resemblance to those of the cretaceous beds of Syria, North Africa, and Southern France, the typical members of the Mediterranean province. The theory of the former existence of land between the South of India and the North of Africa has thus gained additional evidence in its support. The upper cretaceous rocks of the northern and western mountain ranges of India have no connexion whatsoever with the Trichinopoly-Pondicherry series, while the Hippurite-limestone of Persia, Afghanistan and Baluchistan, [3] and the Glauconia-beds of Namcho Lake [4] in Tibet belong to the Mediterranean province. We must therefore seek elsewhere for a connection between the cretaceous seas of Central Europe and of Southern India.

The only remaining means of communication is therefore southwards through Africa, [5] and here we find the famous cretaceous beds of Natal, of which detailed accounts have been published, first by Baily [6] and subsequently by Griesbach.[7] The latter believed that he recognised in Natal all the three lower divisions of the cretaceous rocks of southern India, and he distinguished in the rocks of that country five separate horizons, lying unconformably on the Karoo beds:—

(*f.*) Limestone with *Amm. gardeni* Baily *Sp.*=Ariyalur group. (Senonian.)

(*e.*) Soft sandstone with numerous bivalves and gastropods. (*Fasciolaria rigida* Baily, *Chemnitzia undosa* Forbes, *Protocardium hillanum* Sow., *etc.*) } —Trichinopoly group (Turonian.)

(*d.*) Sandstone with *Amm. umbolazi* Baily, *soutoni* Baily, *stangeri* Baily, *rembda* Forbes, *kayei* Forb., *Anisoceras rugatum* Forb.
(*c.*) Soft brown sandstone (resembling *e*) with *Trigonia shepstonei* Griesbach.
(*b.*) Calcareous sandstone with *Tereda.* } —Utatur group. (Cenomanian.)

(Base of the exposure.)

During the past year, I examined Baily's original specimens in the collection of the Geological Society in London, and had also, through the courtesy of Mr.

[1] P. N. Bose, Mem. Geol. Surv., India, XXI, p. 43.

[2] P. M. Duncan. On the Echinoidea of the cretaceous strata of the Lower Narbada Region. (Quart. Journ. Geol. Soc., London, 1887, XLIII, p. 154.)

[3] *See* Mem. Geol. Surv. of India, Vol. XVIII, p. 34, Vol. XX, p. 140, 143 (Afghanistan), Vol. V., p. 116 (N.-W. Himalaya), etc.

[4] O. Feistmantel: On the occurrence of the cretaceous genus Omphalia, near Namcho Lake, Tibet (Records Geol. Surv., India, 1877, X, p. 21. ff).

[5] In Madagascar also, Newton discovered upper cretaceous species, among which were Ostreæ (O. vesicularis, O. pectinata, O. ungulata), all equally characteristic of the European Senonian and of the Ariyalur group. (Quart. Jour. Geol. Soc., London, 1889, XLV, p. 333.)

[6] W. H. Baily: Description of some cretaceous fossils from Southern Africa (Quart. Jour. Geol. Soc., London, 1855, XI, p. 454 ff.)

[7] C. L. Griesbach: Geology of Natal. (Quart. Jour. Geol. Soc., London, 1871, XXVII, p. 60 ff.

G. C. Crick, the opportunity of seeing, at the Natural History Museum, a new collection of Natal fossils, far surpassing all collections hitherto made. From these, it was evident that certain modifications of the views hitherto held were necessary. It was clear to me from Baily's specimens, that *Schlœnbachia stangeri* and *soutoni* do not belong to the lower cenomanian group of *Schlœnbachia inflata* Sow., as was originally supposed, but to the newer, lower senonian series of *Schlœnbachia tricarinata* Orb. In young forms *Schlœnbachia stangeri* Baily has three keels and only two sets of tubercles, one umbilical, the other external. Those of the latter series show on the ridge a faint linear extension (as in *Schl. tricarinata* type) which becomes more marked as the shell increases in age, and finally develops into a tubercle. Simultaneously, the earlier external series of tubercles extend down the side, while between them and the umbilical series yet another (a fourth) series appears. Finally, the two outer keels break up into a series of elongated tubercles, and even the median keel becomes somewhat varicose; the species then bears a strong resemblance to *Schlœnbachia texana* Rom. from the lower senonian of North America and Central Europe, while *Schlœnbachia soutoni* is a further development of the same type. Both these forms indicate a later age than that hitherto assumed for the beds in which they occur. That this view is correct, appears to me to be distinctly evident from the fact that in the new collection of Natal fossils, a beautiful and well preserved cast of a large fragment of *Schlœnb. stangeri* is associated in the same hand-specimen with *Puzosia gardeni* Baily: both of these species must therefore come from the same horizon. The forms *Puzosia rembda* Forbes, *Lytoceras kayei* Forb., *Anisoceras rugatum* Forb. are derived from the Valudayur group (senonian) of the Pondicherry district, while *Amm. umbolazi* Baily belongs to the somewhat involute *Schlœnbachia* (*Prionocyclus*) group of the lower senonian. (Next to these we have *Am. paon* Redtenbacher and *Am. haberfellneri* Hauer.)[1]

Baculites sulcatus Baily, which evidently did not come under Griesbach's observation, is also a senonian form allied to *Baculites teres* Forb. (*Baculites teres* Stol. from the Utatur group is entirely different.)

I attribute very great importance to the fact that, among the new material already mentioned is a very large specimen of *Amm.* (*n. g.*) *indra*, a characteristic and common form in the Valudayur group. I may also state here that the same species occurs in Vancouver, where it is associated with *Pachydiscus otacodensis* Stol. (an Ariyalur form). A complete account of the interesting facts connected with the investigation of the cretaceous fauna of South Africa will shortly be published by Mr. G. C. Crick.

The above observations are sufficient to justify the assertion that among the cephalopod fauna of Natal, so far as it is at present known, not a single species occurs indicative of a horizon earlier than lower senonian.

The horizon (*e*) has already been correctly identified by Griesbach as the palæontological equivalent of the Trichinopoli group. Almost all species common to both countries occur in India in the Upper Trichinopoli group. Since, therefore, of the known cephalopods of Natal, a large proportion belong to Ariyalur (Valudayur) species (*Puzosia gardeni, rembda, Lytoc. kayei* Forb., *Anisoceras rugatum*

[1] A. Redtenbacher: Die Cephalopodenfauna der Gosauschichten in den nordöstlichen Alpen. (Abhandl. der k. k. Geol. Reichsanst. Wien 1873. Bd. V., p. 131, 133.)

Forb., *Am. indra* Forb.), if the same connection also holds good in the Upper Trichinopoli group—as for example, that of *Schlœnbachia stangeri* and *soutoni* with *Schl. tricarinata* Stol. (non Orb.) of the *uppermost* Trichinopoli beds—then it appears that these latter forms extend beyond zone (*e*) and must be sought for in (*f*) with *Pusosia gardeni.*

There being no fossils on which to base an opinion, none can be offered as to Griesbach's horizons *b* and *c*.[1]

As in India, so also in Natal, which is so closely connected with that country, the cretaceous rocks bear a striking resemblance to those of the Atlantic area, both in their *Schlœnbachia*, which are allied to *Schlœnb, tricarinata* and *texana*, in their *Puzosia gardeni* (connected with *P. pseudo-gardeni* Schlüter), and also in several bivalves (*Protocardium hillanum* Sow., *Janira quinquecostata* Sow.) etc. It is, however, a remarkable fact that just as in the Trichinopoli and Ariyalur groups, so also in the fauna of Natal, the number of central European (or rather Atlantic) species is relatively much smaller than in the Utatur group.

A connecting link between the cenomanian of India and that of Europe is found in the well-known cretaceous rocks on the west coast of Africa, *viz.*, Angola[2] and the Elobi Islands.[3]

The small *Schlœnbachia* fauna of the latter comprises, in addition to *Schl. inflata* (type), another specially Indian variety of this series, and in the same horizon in Angola occurs a *Stoliczkaia dispar* d'Orb., which corresponds exactly with an Indian form distinguished by Neumayr[4] as *Stol. clavigera.* At this stage the bivalve and gastropod fauna of the upper cretaceous beds of Angola begin to show signs of the influence of the Mediterranean province.

Here, however, the connection ceases between the cretaceous rocks of Southern India and those of Europe. Further north, in Morocco and Algiers, we find ourselves in the Mediterranean cretaceous area, the eastern extension of which we found in Narbada, Baluchistan, etc. In the western portion of this area may be seen unmistakeable signs of the connection between the cretaceous faunas of India and of Central Europe (*e. g.*, the fauna of the cretaceous rocks of the south of France, of Algeria, and also the Gosau beds); these, however, become less numerous as we approach the centre of the Mediterranean area. Blanckenhorn[5] figures an *Acanthoceras harpax* Stol. from Syria; I have examined the original specimen, which is in the possession of the Geological Institute of the University of Vienna, and find that, although closely allied to the Utatur form, it is not identical. His

[1] The adoption of a separate lower cephalopod zone (*d*) by Griesbach, is probably due to the fact that the section examined was the face of a cliff undermined by water (Izinhluzabalungu caves) and consequently masses from the higher beds had rolled down, and might be mistaken for independent outcrops. Baily, however, distinctly states that his *Am. Soutoni* was derived from a hard bed "high up the cliff." *l. c.*, p. 455.

[2] P. Choffat and P. de Loriol: Matériaux pour l'étude Stratigraphique et paléontologique de la province d'Angola. Mém. Soc. de physique et d'histoire naturelle de Genève, Vol. XXX, I Partie, No. 2 1888.

[3] L. Szainocha: Zur Kenntniss der mittelcretäcischen Cephalopodenfauna der Inseln Elobi. (Denkschriften d. Akad. d. Wiss, Wien., 1885.)

[4] M. Neumayr: Ueber Ammoniten der Kreide, etc. (Zeitschrift d. deutsch. Geol. Ges. Berlin, 1875. p. 933.

[5] M. Blanckenhorn: Beiträge zur Geologie Syriens, Cassel, 1890, pl. X, fig. 3., pl. XI.

Schlœnbachia cf. *blanfordiana* (Ariyalur type)[1] is too badly preserved to justify any expression of opinion. The fact that the species with which we are concerned disappear in the eastern portion of the Mediterranean area proves that they found their way from the Atlantic, and to a certain extent, from Central Europe, into an otherwise isolated basin.

The cretaceous area of Southern India was connected with that of Central Europe west of the Mediterranean area.

The eastern boundary of the present Atlantic Ocean was already open in later cretaceous times, and a free interchange of fauna between Europe and the south of India was possible by way of Natal and the west coast of Africa.

Nor are there wanting links in the fauna to connect the eastern with the western side of the Atlantic Ocean, as also with Central Europe on the one side and Southern India on the other. For this purpose, great importance attaches to the cretaceous rocks of the Brazilian coast, with which, owing to the efforts of Charles A. White we have for some years been familiar.[2]

White describes the fauna of two separate cretaceous areas in Brazil; that of Sergipe, and the more northerly area of Pernambuco. He comes to no definite conclusion as to the age of these beds, merely assigning them generally to upper cretaceous times, and stating that they are more or less contemporary. Unfortunately, there is at present no detailed account of the stratigraphical conditions, Branner's observations[3] merely indicating several salient features. The area of Lastro, near Maroim, is very rich in important fossils, more especially cephalopods. The ammonites belong mainly to the genus *Schlœnbachia;* in fact, they all appear to be varieties of *Schl. inflata*, while many show affinities to forms found at Angola and figured by P. Choffat. From the same locality, White also describes 2 *Puzosia*, of which he identifies one as *A. planulatus*. From his figure, it appears not improbable that it may in reality be identical with Sowerby's cenomanian species. In the overlying beds, *viz.*, the sandstones of Arœira and the limestones of Garajau a *Puzosia* was found, which was identified by White as *Puzosia hopkinsi* Forb., and which is almost indistinguishable from *Puzosia welwitschi* Choffat, from the Schlœnbachia horizon of Angola. The occurrence of *Aucella braziliensis* White in the cenomanian limestones of Garajau is also very interesting, and forcibly recalls the appearance in India of an *Aucella*, *viz.*, *Aucella parva* Stol. in the beds of the same age. From another locality, connected with Lastro by an Echinoid (*Echinobrissus freitasi* White), a very interesting ammonite had already been described by Hyatt under the name of *Buchiceras Harttii*, and was subsequently figured by White. This figure leaves no doubt that we are dealing with an *Olcostephanus*, in fact one of the peculiarly Indian type of *Am. rudra* Stol. (Neumayr's Stoliczkaia), while the form *Am. pedroanus* White, which is associated with it in Brazil, bears a striking resemblance to *Acanthoceras footeanum* Stol. of the Utatur group. From a calcareous sandstone assigned by Branner to the Lastro horizon, but by White to the succeeding zone—which corresponds better with the palæontological relations—an *Am. folleatus* and an *Am. offarcinatus*

[1] M. Blanckenhorn: *l. c.* pl. xii, Fig. 1, p. 134.

[2] Ch. A. White: Contributions to the Palæontology of Brazil. (Archiv. do Museu Nacion, Janeiro. vol. vii, 1888.)

[3] M. Branner: The Cretaceous and Tertiary Geology of the Sergipe-Alagoas basin of Brazil. (Transact. of the Americ. Philos. Soc. Philadelphia, 1889, vol. xvi, p. 429 ff.)

were figured; both belong to the genus *Acanthoceras*, the first being a member of the group of *Ac. cenomanense*, while the second is a variety of *Ac. mantelli*. We thus see that the *Acanthoceras*-horizon, which plays such an important part in India and Europe, is represented also in Brazil. From the above facts, we may conclude that the extensive fauna of the neighbourhood of Maroim is of cenomanian age, and consequently the overlap in Brazil corresponds to that in Southern India, West Africa and Europe. The limestone of Sapucahy, the most recent member of the Sergipe cretaceous beds, is almost entirely devoid of fossils.

Of a very different character are the cretaceous beds of Pernambuco, which White, on the strength of a few identical species, assigned to the same horizon as those of Sergipe. Ammonites, however, have entirely disappeared, and are replaced by a much more recent type of gastropod. A very important fact concerning these fossils is the occurrence of a form nearly allied to the large and beautiful species *Cerithium pedroanum* White of these beds, in my new specimens from the Ninnyur beds, where it is associated with *Nautilus danicus*. The disappearance of ammonites in the Pernambuco beds is therefore of considerable importance, and clearly tends to show that as in India, at Ninnyur, so also in this area, similar passage-beds exist between the cretaceous and tertiary beds.

There appears to be no connexion between the cretaceous fauna of India and that of the Antilles, to which I shall presently have occasion to refer.

The cretaceous beds of Texas have several points in common with those of India, many more, however, with those of Central Europe; and the same holds good for the other cretaceous areas of North America, so far as they belong to the Atlantic basin, as well as for the band of cretaceous rocks running along the east coast of the United States, and for the great arm of the sea, which at that period included the Mississippi area and the Rocky Mountains.

Since the publication of Römer's work on Texas[1] our views on the subject of the cretaceous rocks of that country have undergone considerable alterations, and his "Cretaceous beds of the highlands" which he assigned to the upper turonian Hippurite series, have now proved to be Rudistes beds of lower cretaceous age.[2] Marine representatives of cenomanian species have quite latterly been discovered in Texas (in the *Cross Timber beds*), but the fauna is very meagre. In the lowest, Colorado group, of Utah has been discovered *Am. swallowi*. Shum,[3] (Hyatt's *Buchiceras*) which is closely allied to *Acanthoceras vicinale* Stol. of the Indian beds. In other respects, the ammonite fauna of the *Colorado group* shows many affinities with that of the turonian of Europe, while the Atlantic section of the ammonite fauna of the turonian of

[1] F. Römer: Kreidebildungen von Texas, Bonn, 1852.

[2] See J. Marcou: American Geological classification and Nomenclature. R. Hill: The Texas secton of the American Cretaceous. (Amer. Journ. Science. 3. Ser. XXXIV. No. 202. 1887. p. 287 ff.) etc.

Great uncertainty prevails, however, as regards the geology of that neighbourhood, and several species, which are undoubtedly upper cretaceous, are cited as being derived from the lower cretaceous Comanche series. See R. Hill: The Cross Timbers in Northern Texas. (Am. Journ. Science. 1887, 3 Ser. vol. XXXIII., No. 196.), where on p. 299 we find *Am. Swallowi, Am texanus, Ananchytes ovatus, Ostrea carinata*, and other species from different horizons of the upper cretaceous beds, included in the Comanche Series. That the lower cretaceous system is well represented in Texas and Mexico, is absolutely certain.

[3] F. W. Stanton: The Colorado formation and its invertebrate Fauna (Bull. U. S. Geol. Surv. No. 106, Washington (1893, p. 168.)

India is too poorly represented to be worthy of special mention. On the other hand, we find among the gastropod fauna, more especially among that of the upper horizons of the Colorado group, many striking resemblances to the Trichinopoli group: thus *Cyrodes conradi* Meek and *Rostellites* (*Fulguraria*) *dalli* Stanton are almost indistinguishable from *Gyrodes pansus* Stol., and *Fulguraria elongata* Stol. (non d'*Orb.*) etc. Such resemblances, however, are not wanting in Europe also. *Placenticeras guadaloupae* Rõmer from the Austin limestone of Texas [1] and even in a greater degree *Placenticeras placenta* Mort., var. *intercalare* Meek[2] of the Montana group of the Missouri basin and the upper cretaceous of New Jersey, bear a remarkable resemblance to the Indian *Placenticeras tamulicum*, which was in fact identified by Stoliczka with the former of the above-named species. Equally closely allied are *Sphenodiscus lenticularis* Mort. and *Sph. siva* Forb.

On the whole, however, the links between the cretaceous beds of the Atlantic portion of North America and those of India are very few; the then-existing distribution of land and sea imposing considerable barriers in the way of any great dispersion of species. Nevertheless, a considerable interchange of forms took place between Brazil and North America on the one side, and Europe, West Africa and Southern India, on the other. Southern India, however, plays a more subordinate rôle, and is only important, in this connection, in so far as it communicated with Central Europe and consequently, indirectly, with these areas. Only in the Brazilian fauna does the special Indian element appear to be of more consequence.

There are certain well-marked types of ammonites which were of exceptional importance in the Atlantic Ocean in cretaceous times, and which are essentially characteristic of that area. They are chiefly represented, in the cenomanian, by *Schlœnbachia* of the group of *Schl. inflata* Sow., with species of *Acanthoceras* and *Turrilites*; in the turonian, by forms of *Prionocyclus* (*Schlœnbachia* in which the keel has become varicose), and frequently *Pachydiscus* of the type *P. peramplus* Mant. In the senonian, *Placenticeras* (of the group of *P. placenta* Mort.), *Baculites*, *Scaphites*, and *Pachydiscus* are very important, while in the lower horizons, the *Schlœnbachia* are largely represented both by the peculiar *tricarinata* group as well as by *Prionocyclus* forms. If therefore we take into consideration all the invertebrata, we can no longer speak generally of an "Atlantic" zoological area, but must picture to ourselves conditions similar to those existing at the present day, that is to say, extremely confined zoo-geographical areas, which, however, contained certain species of very wide horizontal distribution.

Although taking but a subordinate part in the Atlantic area, the cretaceous rocks of India are of very much greater importance in the second great marine province, *viz.*, the Pacific area. Here, owing to the abundance of species, their fauna is of great service, and on it practically depends the possibility of a more accurate description of the stratigraphical conditions of the cretaceous rocks of this area.

If we endeavour to trace the cretaceous fauna throughout this area, we find, in

[1] F. Rõmer: l. c. pl. II. fig. 1. a, c, p. 32.

[2] F. B. Meek: Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri cy. (Report U. S. Geol. Surv. of the Territories, IX. Washington 1876, p. 68 ff., pl. 23.)

See also R. P. Whitfield: Gastropoda and Cephalopoda of the Raritan clays and Greensand marls of New Jersey (Monogr. U. S. Geol. Surv. XVIII., Washington, 1892). pl. XL., fig. 255.

the plateau of Assam,[1] beds which are closely allied by their fauna to those of the Trichinopoli district, the fossils indicating, according to Stoliczka, the presence of strata representing both the Utatur and the Ariyalur groups.

The characteristic fossil of the cenomanian beds of Europe, West Africa, and Southern India, *viz.*, *Schlœnbachia inflata* Sow., was found in the flysch-like sandstones of the Sandoway district of the peninsula of Further India.[2]

In Borneo, upper cretaceous beds occur which are characterised by an abundance of Nerineæ, and yield several species of fossils found in Southern India, amongst which are characteristic Ariyalur forms, such as *Nautilus trichinopolitensis* Blanf. Martin assigned the cretaceous rocks of Borneo to his Eastern Asiatic Province, extending from Japan, through Southern India, to Natal.[3]

In Australia,[4] the cretaceous rocks are exposed over a large area, and have from time to time yielded a considerable number of cephalopoda, including several typical lower cretaceous forms, such as *Crioceras*, etc., and consequently the beds in which they occur, the so-called "Rolling Down Formation," have been assigned to that age. From other localities, however, fossils have been obtained (*e.g.*, a *Schlœnbachia* of the group of *Schl. inflata*, and several Puzosia) which recall the cenomanian forms of India, and it is quite possible that an Indian fauna may also be discovered in Australia. The supposed upper cretaceous beds of that country are very poor in fossils.

So far as the cretaceous fauna of Eastern Asia is known, as for example at Jesso[5] and Sachalin,[6] it is of a well-marked Indian type. A comprehensive work by Jimbo on the cretaceous rocks of Jesso[7] appeared a few months ago, and considerably adds to our list of Indian types of ammonites. An especially important part is played by *Lytoceras* of the *Lytoceras Sacya* group which is also represented in India by a great variety of forms; we may also mention *Phylloceras*, *Pachydiscus*, etc., while *Acanthoceras*, of the *rhotomagense* type, is no longer unknown in the Pacific area. A large number of allied, as well as several identical species connect the cretaceous rocks of Japan and Sachalin to the Utatur group; thus we find *Lytoceras sacya* Forb., *Phylloceras velledæ* Mich., and *Acanthoceras rhotomagense* var. *asiaticum* Jimbo, also in the Utatur group. We can also trace a connection with the Trichinopoli group, for a form allied to *Pachydiscus peramplus* has been found at Jesso, while large and numerous specimens of a similar form had already been discovered at Sachalin. Very large also is the number of Japanese species of *Pachydiscus* which are closely allied to, or rather identical with Ariyalur forms.

[1] H. B. Medlicott: Geological Sketch of the Shillong Plateau in N. E. Bengal. (Mem. Geol. Surv. India. VII. Calcutta. 1871. p. 181. ff.).

[2] W. Theobald. Records Geol. Sur., India, V, Calcutta, 1872, p. 82.

[3] K. Martin. Die Kreideformation von Martapoera (Borneo). Sammlungen des Geol. Reichsmuseums in Leiden. Ser. I, Vol. IV, 1889, Heft 5, 6, p. 142.

[4] R. L. Jack and A. Etheridge. The Geology and Palæontology of Queensland and New Guinea. London 1892, p. 390 ff.

[5] M. Jokoyama. Versteinerungen aus der Japanischen Kreide. (Palæontographica, XXXVI Cassel 1889-90, p. 159 ff.)

[6] F. Schmidt. Die Petrefacten der Kreideformation von der Insel Sachalin (Mem. de. l'Académie Impériale des sciences de St. Pétersbourg, VII. Ser. Tome, XIX. Nr. 3, 1873.

[7] K. Jimbo. Beiträge zur Kenntniss der Fauna der Kreideformation von Hokkaido. (Palæontologische Abhandlungen. Bd. VI, Heft 3, Jena, 1894.)

So striking is this fact, that Harada, Jokoyama, and now also Jimbo have concluded that the fauna of Japan must be considered as the result of an intermingling of forms from every possible horizon of upper cretaceous age, and that no division of the rocks into distinct horizons with characteristic fauna, can be attempted. But until we have a detailed account of these areas, little importance must be attached to the above statement, for in cretaceous beds, widely separated from India, *viz.*, in the Pacific section of North America, the Indian species occur in a succession almost identical with that seen in the beds of that country.

An especial interest attaches to the coal-bearing cretaceous rocks of Queen Charlotte's Islands[1] in the North-Eastern Pacific. The most fossiliferous bed of the cretaceous rocks of that area is Richardson's division C., which strongly resembles the Volga Series of Russia, not only in the occurrence of *Aucella*, to which fact the greatest importance has hitherto been attached, but also in the presence of many ammonites. Thus, for example, *Am. skidegatensis* Whiteaves[2] differs but very slightly from *Olcostephanus pallasi* Kaiserling, while several other varieties of *Olcostephanus* occur, and I cannot accept Whiteaves' view that the bed C. is equivalent only to the Gault. In the highest zones of this division can be seen numerous unmistakeable signs of a connection with the Utatur group; we find the same *Lytoceras Sacya* as in Japan and India, as well as *Schlœnbachia inflata*, *Lytoceras timotheanum* May, etc.

The overlying conglomerate, which is apparently the equivalent of the Dakota group is almost entirely devoid of fossils, but the higher shale beds, the "Upper Shales," have yielded *Inoceramus problematicus* Schloth., a common form in the Colorado group of the Atlantic section of North America and in the turonian of Europe.

We have, therefore, in Queen Charlotte's Island, a conformable series, extending from the lowest to the upper cretaceous beds. The most recent investigations also reveal very similar conditions in Northern California.[3]

To the west of the Upper Sacramento Valley a continuous series of cretaceous rocks is exposed: first, the Knoxville beds with *Aucella*; above these, the Horsetown beds, and at the summit, the upper cretaceous Chico group. The Knoxville and lower Horsetown beds yield lower cretaceous fossils, while in their uppermost horizons, the latter beds contain *Schlœnbachia inflata* Sow. and *Lytoceras sacya* Forbes, exactly as in the upper horizon of division C. in Queen Charlotte's Island. The lower Chico beds of Mt. Diablo have for some time been known to contain an *Acanthoceras* of the *rhotomagense* type, *viz.*, *Acanthoceras turneri* White,[4] which species I also obtained from the Utatur group of India.[5] In the upper beds of the Chico group, in addition to baculites of undoubted senonian facies, is found *Pachydiscus newberryanus* Gabb (non Meek), which is very nearly allied to *P.*

[1] J. F. Whiteaves. Mesozoic Fossils. (Geol. and Nat. Hist. Surv. Canada) Vol. I, pt. I and III Montreal, 1876 and 1884.

[2] J. F. Whiteaves. l. c. Pt. I, pl. IX, fig. 1 p. 34.

[3] J. S. Diller and T. W. Stanton. The Shasta-Chico Series, (Bulletin of the Geol. Soc. of America). Vol. V, pp. 435-464. Rochester, 1894.

[4] Ch. A. White: On invertebrate fossils from the Pacific coast. (Bulletin U. S. Geo. Surv. No. 51 Washington 1889. pl. V. p. 26.)

[5] The identity of the two forms was confirmed by Ch. A. White, to whom I sent a figure of the Indian specimen.

otacodensis Stol. It is a very interesting fact that the Chico group, the lowest beds of which consist entirely of conglomerate and sandstone, overlaps the older strata of the so-called Shasta-Chico Series and over extensive areas in Washington, Oregon and California, lies directly on the older metamorphic rocks. The occurrence of a cenomanian *Acanthoceras* in the lower Chico beds, and of the lower cenomanian forms, *Schlœnbachia inflata* and *Lytoceras sacya* immediately below them proves that this overlap was almost contemporary with that of India, West Africa and Europe, etc.[1] The Chico group is known to extend to latitude 29° 30' N. (Lower California.) Beds resembling those of the Chico group, occur also further north in the Island of Vancouver,[2] where they are characterised by the number and excellence of their fossils. In the British Museum, in an old collection made by Hector and mentioned by Whiteaves, but not hitherto examined, I observed not only an excellent specimen of *Am. indra* Forb., but also, from the same beds the typical *Pachydiscus otacodensis* of the Ariyalur group, not hitherto identified in North America, and several other *Pachydiscus* forms, some of which were new, as well as *Baculites occidentalis* Meek, which is closely allied to the Indian *Baculites vagina*, etc. Whiteaves mentions the occurrence of *Puzosia gardeni* Forb. in the Chico group of Vancouver, while his *Lytoceras jukesii* (?) Sharpe is apparently identical with *Lyt. kayei* Forb.: the number of Indian species is therefore very considerable. So far as the fauna of the Pacific area of North America has hitherto been identified, the succession of the horizons is very similar to that seen elsewhere. In the upper Horsetown beds occur *Schlœnbachia inflata* and *Lytoceras sacya*, and next above them, in the lower Chico group, *Acanthoceras* followed in the upper *Chico group* by *Pachydiscus* and baculites.

Our knowledge of the other cretaceous rocks on the Pacific side of America is very meagre. In Chili unmistakeable upper cretaceous beds occur. In the Natural History Museum in London, I saw the specimens of *Baculites vagina* Forb.,[3] from Conception Bay, which are mentioned in Darwin's work on South

[1] Since a single "Shasta-Chico Series" has been established, extending from the lowest to the upper beds of cretaceous age, the question as to the date of the folding of the Sierra Nevada and coast ranges has assumed a new aspect. If the altered *Aucella* (Mariposa) beds of the Sierra Nevada, which are unconformably overlapped by the Chico beds, are of the same age as the lower Knoxville beds of the Shasta-Chico series, then the folding of the Sierra Nevada and the coast ranges would certainly be intercretaceous, a view which formerly met with general acceptance. Folding then took place simultaneously with that in Mexico, while at the same time, uninterrupted sedimentation was proceeding in the Upper Sacramento Valley and further to the North. (Queen Charl. Isl., Rocky Mts. and British Columbia). After the completion of the folding, the sea again flowed over the newly-formed mountains, and upon them the Chico beds were laid down. According to another view, however, the Mariposa beds are of Jurassic age, and consequently older than the Knoxville beds, and the folding took place previous to the deposition of the latter. See H. W. Fairbanks: The pre-cretaceous age of the metamorphic rocks of the California Coast Range, (Americ. Geologist. March 1892. p. 153 ff.). At present our data are too scanty to enable us to arrive at a decision of any value. This one important fact, however, is certain, that in upper cretaceous times (Chico period) the Sierra Nevada formed the western coast of a continent, the Great Basin, which extended eastward from that range.

[2] J. F. Whiteaves l.c. Pt. II. On the fossils of the Cretaceous Rocks of Vancouver, etc. Montreal, 1879.

[3] Ch. Darwin: Geological observations on the volcanic islands and parts of Southern America, 2 edit., London, 1876, p. 397.

America. These differ in no particular from the Indian specimens. At the Geological Congress held recently in Zurich, Prof. Steinmann,[1] speaking on the cretaceous rocks of Chili, said that, on investigation, he had indentified *Phylloceras* and *Lytoceras* forms connecting the beds of that country with the Utatur group of India. There may therefore be in the upper cretaceous rocks of Chili both Utatur and Ariyalur forms.

In general type, the cretaceous rocks of the Pacific area can be readily distinguished from those of the Atlantic province. Time has proved indeed that almost all species occurring in the one are also represented in the other, but often in a much less degree. Thus, for instance, *Schlœnbachia* and *Acanthoceras*, although not unknown in the cenomanian of the Pacific area, occur but rarely, and are quite out-numbered by a profusion of *Phylloceras* and *Lytoceras* forms, (the latter more particularly of the *Lyt. sacya* type). On the other hand *Desmoceras* and *Puzosia*, which are of rare occurrence in the upper cretaceous rocks of the Atlantic area, are here comparatively common, while *Holcodiscus*, which is not known to occur in the upper cretaceous beds of the Atlantic area, is represented in India by an abundance of forms. *Pachydiscus* and *Baculites* are more or less equally distributed in both hemispheres, being represented, however, by different species. It is impossible, therefore, nor would it be advisable, to enunciate shortly a hard-and-fast distinction, which on further investigation might prove to be erroneous, for only quite recently has it been shown by Jimbo that the true Atlantic type of *Placenticeras* and *Acanthoceras* (of the *rotomagense* group) occurs also in Japan.

On the whole, however, the cephalopod fauna of the upper cretaceous rocks in the Pacific area is not so rich in new forms as is that of the Atlantic province, the majority being closely connected with lower cretaceous forms; and this "conservative tendency," noticed by Neumayr[2] in the cretaceous fauna of Southern India, is, so far as we are at present aware, to a great extent peculiar to the Pacific area. The commingling of both types, which in India was so intimate that they almost balanced, is quite unknown in the cretaceous rocks of the west coast of America, which are much more closely related to the Atlantic area than are those of India.

The great difference between the cretaceous rocks of California and those of the Rocky Mountains, which are of the Missouri type, has long been known, and American geologists completely separate these two areas,[3] not only on accoűnt of the constitution of their fauna, but also on account of their geological conditions. As we approach the Great Basin, the cretaceous beds of the Rocky Mountains and of the Colorado plateau increase in thickness, and we find intercalated, at widely separated horizons, seams of coal and beds containing brackish or fresh-water shells; thus indicating the proximity of the western coast of the ancient continent, the Great Basin, which was subjected to folding in post-jurassic times, and from which cretaceous beds are entirely absent; while on the other side of the Sierra Nevada, we meet with the completely different cretaceous rocks of California.

[1] G. Steinmann: Procès-Verbaux des Séances des Sections 30. 8. Congrès Géologique international VI. Session à Zurich, 1894 pp. 6, 10.

[2] M. Neumayr: Erdgeschichte, Bd 2, p. 390.

[3] See Ch. A. White (Bull. U. S. Geol. Surv., No. 15, p. 30.)

An interesting addition to these facts was contributed by Hill,[1] in his investigations of the cretaceous rocks of Mexico. He discovered that the lower cretaceous (Comanche series of Texas) of the Mexican Sierras almost extends from ocean to ocean. Before the deposition of the upper cretaceous beds, however, these rocks were subjected to folding, and the next series (upper cretaceous) was then laid down, which, as may be seen in the Missouri district in the east, lies unconformably upon them. During upper cretaceous times, the lofty mountain folds of the Great Basin region of North America formed dry land, extending as far as British Columbia.

In the north of British Columbia we encounter somewhat different conditions. It has already been stated that the Upper Shales of Queen Charlotte's Islands yield *Inoceramus problematicus* Schloth., which is also frequently met with in the cretaceous rocks of Missouri. On the mainland of British Columbia between the parallels of 49° and 51° 30', Dawson discovered a bed resting on the *Aucella*-bearing Kootanie Series, which latter is the littoral representative of the Shasta group, or more particularly of Div: C of Queen Charlotte's Islands. This bed is a conglomerate similar to that found in Queen Charlotte's Islands, and is overlain by the clay of the Colorado group and by upper cretaceous beds extending to the Laramie Series.

In the same locality, it was also possible to identify with certainty upper cretaceous beds of Atlantic type resting upon lower beds of Pacific type, and the occurrence of *Inoceramus problematicus* in Queen Charlotte's Islands is a proof that the same conditions prevail there also. Hence we see that a connection resulting in overlap existed between the Atlantic beds and those of the Pacific area, which during lower cretaceous times extended to the eastern spur of the Rocky Mountains.[2] The interchange of fauna, thereby rendered possible, seems however to have been quite insignificant, the admixture in the Chico group of forms from the Atlantic portion of North America being very trifling.

The conditions prevailing in the northern districts of South America and in the Antilles, are very interesting. In Jamaica, corals[3] have long been known to occur of which several are identical with those of the Gosau beds, while hippurites are associated with them, and an *Actæonella* also has been stated to occur; all the above being fossils which undoubtedly occur in the Mediterranean cretaceous area. In striking accord with the above facts is the discovery in Peru[4] of an *Actæonella* and

[1] R. Hill: The Cretaceous Formation of Mexico and their relation to North American Geographic Development. (Am. Journ. of Science, 3, Ser., XVL, No. 268, 1893, p. 307).

[2] J. F. Whiteaves, too, finds that the upper cretaceous rocks are more nearly related to those of the eastern area than are the rocks of the more southern Chico group of California (l. c. Vol. I, Pt. II, p. 187) which is further evidence in favour of the above connection.

On the whole, Whiteaves agrees with Gabb in supposing that communication was carried on through the southern area, and adduces as evidence in support of his view the fact that cretaceous rocks occur to the west of the Sierra Madre in Mexico. But in the Chico period the coast extended much further west, embracing Lower California, while the fauna also of that district is entirely different to that of Mexico and Texas.

See also Ch. A. White: Notes on the Mesozoic and Cenozoic Palæontology of California (Bull. U. S. Geol. Surv. No. 15, Washington 1885), p. 30, and R. Hill: Cret. Format. of Mexico etc., p. 319.

[3] S. M. Duncan and G. P. Wall; A notice on the Geology of Jamaica (Quart. Journ. Geol. Soc., London, XXI, 1865), p. 2, ff.

[4] W. M. Gabb; Description of a collection of fossils made by Dr. A. Raymondi in Peru (Journ. Acad. Nat. Science Philadelphia, 2, Ser. Vol. VIII. Part III, Art. X, 1877, see pl. 36, fig. 1, a, b, p. 264 etc.)

of typical Mediterranean ammonites, closely connected with "*Buchiceras*" *syriacum* Buch. Such a fauna cannot fail to have been derived from the Mediterranean, and the assumption is therefore inevitable that an arm of the sea stretched across America, most probably in the neighbourhood of the Antilles and the modern Cordillera region of the northern part of South America, thus rendering possible the migration into the Pacific area of exclusively Mediterranean types. It was formerly supposed that the form "*Buchiceras*" *hartlii* Hyatt, found in Brazil was connected with those discovered in Peru, and consequently it was assumed that communication had originally been possible by means of the valley of the Amazon. We can now however, recognise the former existence of two arms of the sea, which divided America as it existed at that period into two great insular portions, constituting the boundary between the Pacific and Atlantic Oceans.

The cretaceous rocks of Southern India are more or less closely connected with a very large number of rocks of that age occurring in other countries, and are consequently well adapted to serve as their type. The European beds on the other hand, being merely a typical sub-division of the Atlantic area, are of but little service in this respect, and frequently fail us if we endeavour to correlate them with the cretaceous rocks of the Pacific. The great importance of the cretaceous beds of Southern India was therefore speedily recognised, but their connection with those of the Atlantic area has been much under-estimated.

In reality, the fauna of Southern India comprises the most important types of both the great areas and thus serves as a connecting link between them.

The marked contrast between the cretaceous rocks of the Atlantic area, and those of the Pacific consists not only in the great difference of extension of the overlap, but also in the independence of their respective fauna. This is particularly striking in America, but disappears to the south of the ancient Indo-African continent.

I have now stated in general terms the most important facts bearing on the geographical conditions which prevailed in upper cretaceous times. No other system offers such a profusion of material for a detailed reproduction of those conditions, and it is my intention, as soon as possible, to embody these in the form of a chart.

In conclusion I should like to enter briefly into a few general questions.

Neumayr ascribes great importance to the influences of climate, more especially as regards the horizontal distribution of the Ammonoidea. This question has received a considerable amount of attention,[1] and it is now probable that the dispersion of the cephalopods was due less to the effects of climatic influence than to those of the distribution of land and sea, and the consequent facilities for migration. The ammonite fauna of Central Europe is at least as intimately connected with that of Southern India, as with that of the Mediterranean. Now the climate of Central Europe cannot have differed widely from that of the Mediterranean, while on the other hand that of Southern India was tropical, and the similarity in fauna must be due to migration of species from one hemisphere to the other by way of Natal. Even disregarding any possible deductions from the present climate, we can still establish

[1] S. Nikitin. Einiges uber den Jura in Mexico und Centralasien. (Neues Jahrb., Vol. II, 1890, p. 273, ff.)

A. Tornquist. Fragmente einer Oxfordfauna von Mtaru (Deutsch Ostafrika). Jahrb. der Hamburger wissenschaftlichen Anstalten. X. 2. Hamburg, 1893, p. 24.

the tropical character of the cretaceous fauna of Southern India, both by means of the reef-building corals and also, though in a lesser degree, by the presence and luxuriance of the gastropod and bivalve fauna. The argument in favour of a tropical climate based by Neumayr on the occurrence of *Phylloceras* and *Lytoceras*, applies equally well to the whole Indo-Pacific region. In that area, these forms are found in districts which, according to Neumayr, during the preceding Jurassic and lower cretaceous periods were closely connected with the Volga beds, that is to say, with the Northern basin. The less extensive faunas, inhabiting smaller and more isolated seas, may possibly have been less independent of climatic influences; but it is very difficult to decide with any degree of certainty the amount of importance to be attached to this factor.

The wide distribution of the Ammonoidea, which so complicates the question of climatic influence, induced Professor J. Walther[1] to believe that on the death of the ammonites, their floating shells became filled with air, and were borne hither and thither by winds and currents. He consequently concludes that their wide distribution was due, not to migration during life-time, but to a subsequent transportation of the empty shells. He even considers himself justified in propounding the theory that " the Triassic, Jurassic and Cretaceous systems may, for the most part, each be distinguished by a single species of ammonite, and may thus be recognised with facility in any part of the globe" : and again," during a given geological period, some one species of ammonite was uniformly distributed over the whole sea-floor, and after a short existence, became everywhere simultaneously extinct and was everywhere simultaneously replaced by a new species." The above statements involve a gross exaggeration of the true state of the case, for if we study the fauna of any given period over the whole earth, we find that in reality the phenomena are highly complicated. In the majority of cases, those species by means of which we correlate widely separated areas, are not identical, but are merely closely allied forms: *i.e.*, geographic variation involves variation of species.

The more careful our observations, the more frequently do we find that in numerous cases, species originally supposed to be identical, are in reality only members of similar groups, which may be distinguished from o..e another by certain constant characteristics. Thus, for example, we find in India neither *Acanthoceras rhotomagense* Defr., *Mammites nodosoides* Schloth, *Pachydiscus peramplus* Mant., *Schlœnbachia tricarinata* Orb., *Placenticeras syrtale* Mort, nor *Baculites anceps* Lam.; closely allied forms, however, do occur, and these are found in an exactly similar stratigraphical relationship, and are evidently their representatives. Very similar examples of this may be seen if we compare the cretaceous fauna of Brazil, Japan or North America with that of India.

It is, however, undeniable that there are species, several of which I have already had occasion to mention, which, by their constant characteristics, may be recognised in almost every part of the world. Thus *Lytoceras timotheanum* May has been found in Europe, India, Sachalin, and Queen Charlotte's Islands. In Europe, it is connected with contemporaneous and also with older forms, while its descendants are found in India in the Trichinopoli and Valudayur groups; nearly allied forms also occur at Jesso. If, however, its presence in any given area were due to

[1] J. Walther: Einleitung in die Geologie als historische Wissenschaft, II. Th. Jena., 1893-94. (Die Ammoniten als Leitfossilien, p. 508. ff.)

marine transportation, it would there be isolated and not found in association with allied forms. Many other examples of a similar nature are to be seen in *Desmoceras*, *Puzosia*, *Pachydiscus*, *Acanthoceras*, *Schlœnbachia*, *Hamites*, etc. Any further demonstration of the fact would, however, be valueless without palæontological details. Hence we see that there are certain widely dispersed species of ammonites, which are found to be distributed in such a manner that we are compelled to assume an independent migration.

Very similar conditions prevailed during Triassic and Jurassic times: and the above facts prove that in all such cases the animals lived in the localities in which their remains have been found. The possibility of the occasional transportation of the empty shells need not be contested. Walther's theory, however, has no special bearing on the question of the zoo-geographical conditions.

If we compare the horizontal distribution of the ammonites with that of other forms of animal life, we find that it is by no means so abnormal as to necessitate an explanation other than that of simple migration. Thus, for example, in Southern India, associated with European ammonites, we find also European brachiopods, bivalves and gastropods, though certainly in smaller numbers. If again, we compare the conditions prevailing at the present day, we find numerous striking examples of the wide distribution of many marine shells. Thus, for instance, species are now living which are common to Natal, Ceylon, the Philippines, Japan, and even the coast of Australia;[1] and Fischer draws special attention to a considerable number of gastropods which are found both in the Indian Ocean and at the Antilles.[2] Similar, if less striking examples might be added—there is even an unmistakable resemblance in the distribution of the modern fauna[3] which, however, is not to be wondered at, if we consider the great resemblance existing between the geographical conditions during later cretaceous times and those prevailing at the present day.

Report on the Experimental Boring for Petroleum at Sukkur, from October 1893 to March 1895, by T. H. D. LATOUCHE, B.A., *Superintendent, Geological Survey of India.*

The actual drilling of the Sukkur boring was commenced on the 19th December 1893, the previous two months having been spent in bringing down from Babar Kuch the boring plant, which had been in use at the Khattan oil-wells, in selecting and repairing such portions of it as were suitable for the Sukkur boring, and in erecting the drilling rig and derrick. The site had been provisionally selected by Dr. King, late Director, Geological Survey. The reason of this choice was not that there was a greater probability of obtaining oil at that spot than at any other in the neighbourhood of Sukkur or Rohri, for at that time no surface indications of

[1] P. Fischer: Manuel de conchyliologie. Paris, 1887, tome. I. p. 158.

[2] P. Fischer. l. c. p. 177.

[3] See Fischer's chart, p. 126.

the presence of oil had been found anywhere in Upper Sind; it was merely a matter of convenience, for, being close to the North Western Railway workshops, repairs to the machinery could be carried out with as little delay as possible, while it was also at a convenient distance within the area of outcrops of the upper nummulitic limestone, the base of which forms a well-defined horizon for comparative measurements in relation to sections or borings in other localities.

Progress of the boring.

In the first place a well or sump was excavated down to the level of the surface water, which was found at a depth of about 10 feet. A length of 8-inch casing was then put in and sunk through the alluvial sandy clay overlying the limestone until the eroded surface of the latter was struck at a depth of 38 feet 6 inches. Now that experience has been gained of the nature of the rocks beneath the limestone, it is evident that it would have been better to have started with a larger diameter of casing than 8 inches, as this would have greatly facilitated subsequent operations; but, at the time the boring was begun, it was not anticipated that the hole would have to be lined with casing to so great a depth.

After the limestone was struck on the 23rd December 1893, at which date work was stopped till the end of the year, the progress made may be summarised as follows:—

Month.	Progress made.		Total depth.		Remarks.
	Ft.	Ins.	Ft.	Ins.	
January 1894	281	0	324	0	The base of the limestone was reached at 140 feet from surface. The boring then entered beds of shaly blue clays, with thin bands of limestone and nests and veins of gypsum.
February "	76	0	400	0	Drilling much retarded by clogging of tools. Six-inch casing was put in to a depth of 167 feet.
March "	17	7	417	7	Greater part of month spent in substituting 7-inch casing for the 6-inch and in putting down the latter to the bottom of the hole.
April "	75	5	493	0	A thick band of limestone was passed through at 409 feet, which prevented the casing from going down. The casing had to be drawn out and the obstruction cut away.
May "	*nil*		...		The whole month was spent in lining the hole with 6-inch casing. The tools became jammed in the hole on the 12th, and were not recovered till the 21st. The 6-inch casing was put down to 440 feet, but could be sunk no further, and a string of 4½-inch casing was therefore put in.
June "	47	0	540	0	Drilling proceeded till the 8th, when the 4½-inch casing refused to go further. The 6-inch casing was driven down to 464 feet.

Month.	Progress made.		Total depth.		Remarks.
	Ft.	Ins.	Ft.	Ins.	
July 1894 .	5	0	545	0	The whole month was spent in trying to get the 6-inch casing past the obstruction at 464 feet. On the 13th the sand pump was lost in the hole, and was not recovered till the 28th. Subsequently, the 6-inch casing was driven down to 525 feet.
August " .	87	0	632	0	The 4⅝ inch casing was put in again. From the 6th to the 23rd repairs were being made to the engine and boiler.
September " .	113	0	745	0	Progress was more rapid this month, as the casing followed the tool down and was not stopped by bands of hard rock.
October " .	134	6	879	6	Indications of gas were observed at about 785 feet, and water was struck at about 865 feet.
November " .	78	0	957	6	The 4⅝-inch casing, which had now reached a depth of 917 feet, would not go further, and it was therefore pulled out and the lining of the hole continued with 6-inch casing by the aid of an under-rimer.
December " .	*nil*		...		Putting in the 6-inch casing. Repairs to the engine and boiler were done between the 6th and 15th.
January 1895 .	6	0	963	6	Putting down 6-inch casing. Struck a band of hard limestone at 958 feet.
February " .	79	0	1,042	6	Drilling proceeding fairly steadily, though slowly. The band of limestone at 958 feet proved to be only 20 feet thick. The hole was lined with 6-inch casing to 1,023 feet.

Since the beginning of March progress has again been very slow, and up to the present about 40 feet have been drilled. Two more lengths of 6-inch casing have been put in, making a total of 1,056 feet now in the hole, but these last two lengths have been driven down with much difficulty, and it is hardly likely that much more casing of this size can be used. It is, however, more than we expected it would be possible to introduce, and of course it is a great advantage to have the hole perfectly clear to such a depth, for it will considerably facilitate the progress of the smaller casing, which will shortly have to be put in.

Character of the strata beneath the limestone.

The shales and clays beneath the limestone are of very uniform character throughout the whole distance—about 940 feet—passed through up to the present, the only exception being the occurrence of thin bands and nodules of hard grey limestone; and there can be no doubt, as pointed out by Mr. Griesbach, that they are the same beds as those found in a similar position beneath the upper nummulitic limestone in Baluchistan, as, for instance, in Mudgorge on the Hurnai Railway. What their thickness may be at Sukkur it is impossible to say, for the

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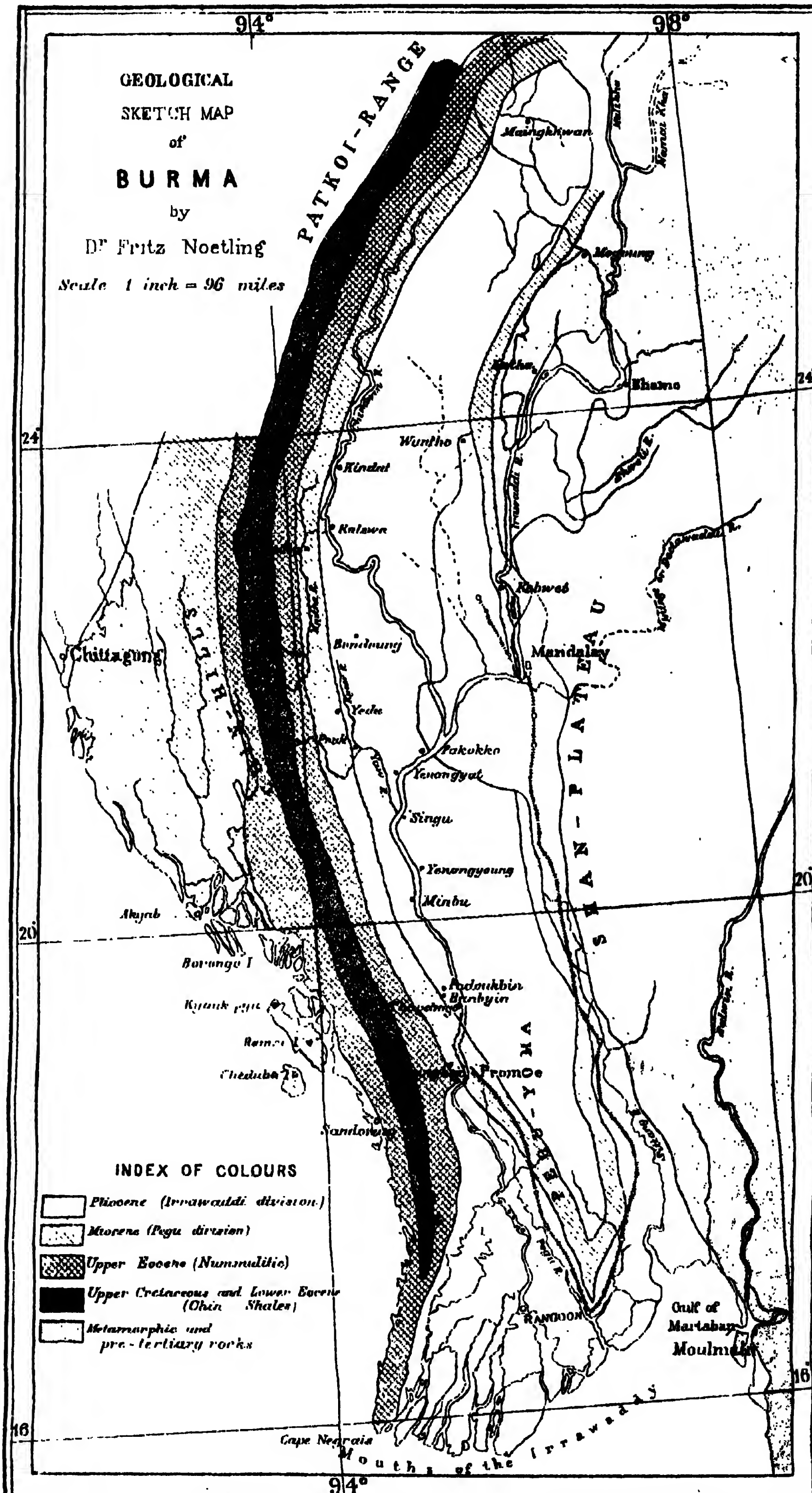
different members of the tertiary system vary considerably in thickness in different localities, and no measurements made in the hills to the west of Sind can be relied on to furnish an estimate of the thickness at Sukkur. They may continue without much change for another thousand feet, or, again, the underlying rocks, which it is to be hoped are of more solid character, may be reached at any moment.

Future prospects of boring.

Under these circumstances it is difficult to offer any opinion as to the future prospects of the boring, that is to say, as to the depth to which it should be carried before hopes of a successful issue are abandoned. But a discovery has quite recently been made in the neighbourhood of Rohri, on the other side of the Indus, which seems to point to there being a certain depth at which oil, if it exists in any quantity, should be met with, and to this depth I think that the boring should certainly be carried; and now that so much of it has been lined with 6-inch casing, there should be no great difficulty in doing this. I have already reported on the discovery alluded to, but it may be well to call attention to the facts here, and the conclusions I have drawn from them so far as they affect the Sukkur boring.

Traces of oil at the surface near Kundra.

My attention was recently called by His Highness the Mir of Khairpur to the fact that some peculiar gas had been observed for many years to issue from the soil at a spot about three miles to the west of Kundra, a village eight miles south of Rohri. I visited the place soon afterwards and noticed that the gas appeared by its odour to be similar to that observed in the boring at Sukkur; and recently I had a well dug at the spot so as to reach water, which was found at about 20 feet from the surface. After reaching a depth of 16 feet or so the gas, which is apparently carbonic acid, as it does not support combustion, issued in such volumes as to prevent the men working in the well, and the sinking had to be carried on from above. On examining the water, after emptying it out and allowing it to flow in again several times, distinct traces of oil appeared on the surface in the shape of iridescent films, and, on dredging up the sand from the bottom, these films could be seen oozing out from it and spreading over the surface of the water. The place is well out on the alluvium of the Indus valley, no solid rock being seen anywhere between it and the ridge of limestone running south from Rohri, which lies at about six miles distance to the east. Now, if we knew the thickness of the alluvium and the dip of the beds, it would be easy to calculate from what horizon in the rocks beneath the limestone these traces of oil escape, supposing that they escape from the outcrop of the rocks beneath the alluvium and do not rise through some fissure. Consequently, we should know at what depth we might expect to meet with them in the Sukkur boring. Estimating the thickness of the alluvium at 300 feet, and the dip at 2° to the east, which is about the average dip seen in the hills, the thickness of beds between the base of the limestone and the horizon at which the oil escapes works out to about 1,500 feet; and, as the base of the limestone at the Sukkur boring is 140 feet from the surface, the total depth to be drilled in order to reach that horizon should be a little over 1,600 feet. Of course the alluvium may be of greater or less thickness than I have estimated. This can only be determined by a boring at the spot; but the difference, whatever it may be, should be added to or substracted from the estimate above given, in order to determine the depth to which the Sukkur boring should, in my opinion, be carried before being abandoned.


GEOLOGICAL
SKETCH MAP
of
BURMA
by
Dr. Fritz Noetling
Scale 1 inch = 96 miles
94°
98°
24°
20°
16°
PATKOI-RANGE
Chittagong
Akyab
Kindat
Kalewa
Wuntho
Bhamo
Kabwet
Mandalay
Pakokko
Yenangyat
Singu
Yenangyaung
Minbu
Padaukbin
Prome
Sandoway
Rangoon
Gulf of Martaban
Moulmein
SHAN-PLATEAU
Cape Negrais
Mouths of the Irrawaddy
INDEX OF COLOURS
Pliocene (Irrawaddi division)
Miocene (Pegu division)
Upper Eocene (Nummulitic)
Upper Cretaceous and Lower Eocene (Chin Shales)
Metamorphic and pre-tertiary rocks

The Development and Sub-division of the Tertiary system in Burma, by DR. FRITZ NOETLING, F.G.S., *Palæontologist, Geological Survey of India.* (With a map).

HISTORICAL SUMMARY.

In the following summary of the former geological work done in Burma, I shall restrict myself to a review of those papers which deal with Lower and Upper Burma, that is to say with that part of Further India which is situated between the Shan hills in the east and the Arrakan Yoma in the west, and which represents, properly speaking, the country of Burma. I shall therefore disregard all papers dealing with the geology of Tenasserim and Arrakan.

Although, since the end of the last century, Burma has been visited by numerous travellers. who have related their experiences in various publications, the outcome of these travels has been very poor, with regard to the geological knowledge of the country. This is the more remarkable in that Burma has been famous for its mineral wealth, and nearly every traveller had in view the enormous mineral resources of the country. The meagre results are doubtless due to the want of geological training of most of the travellers, and this in its turn might again account for the legend of the enormous mineral wealth of Burma.

Among the names of those who wrote on geological subjects connected with Burma, previous to the researches of Dr. Blanford, Mr. Fedden, and Mr. Theobald, two only deserve mention, but they shine with the greater brilliancy amongst the numerous amateur attempts to deal with the geology of Burma: these are the names of Dr. Buckland and Dr. Oldham.

As early as 1829, from specimens which had been collected by Mr. Crawford in Upper Burma, and brought by him to England, Dr. Buckland recognised the following formations:—[1]

1. Alluvium.
2. Diluvium.
3. Fresh-water marl.
4. London-clay and calcaire grossier.
5. Plastic clay with its sands and gravel.
6. Transition limestone.
7. Grauwacke.
8. Primitive rocks, marble, mica slate.

Considering the state of geological science at that period, it is astonishing how accurately Dr. Buckland has recognized the formations which occur in Burma. It is unnecessary here to deal with his groups 6 and 8, as, for the purposes of this paper, we are mainly interested in the younger formations; but, with regard to these, it must be said that Dr. Buckland has already recognized some of the most important sub-divisions of the Burma tertiaries. Had he not been led by a mistaken inference to suppose that the fossil bones were also found in diluvial beds in Burma, he would, in fact, already have fixed the great divisions into which the tertiary rocks of Burma can be divided. If we substitute "Upper Tertiary" for the word "Diluvium," or if we keep in mind the fact that his diluvium really represents tertiary strata, we shall see that Dr. Buckland has already sketched in

[1] Transact. Geolog. Soc., 2nd series, 1829, vol. ii, p. 377.

broad outlines the sub-division of a part of the tertiary system in Burma, which still holds good at the present day. His diluvium and fresh-water marl represent the two groups into which I have divided the Burma strata, *viz.*, the upper ossiferous Irrawaddi division and the Yenangyoung division; the "London clay" represents the Pegu division, as is unmistakeably proved by the list of fossils, and if we unite his group No. 5 with the London clay, the three upper divisions of the Burma tertiaries are at once recognized.

That the nummulitic formation was overlooked is easily explained; when we remember that its outcrops are only visible far away inland at places that Mr. Crawford could not visit.

Dr. Buckland however, was, mistaken in identifying a piece of rock from Minlindoung near Yenangyoung with the "Grauwacke" formation of Europe, as, no such strata occur within the neighbourhood of Yenangyoung, particularly at the said hill, which is entirely built up of tertiary strata.

It is much to be regretted that no opportunity for the study of the geological formations of Burma was afforded to Dr. Oldham, beyond those casual visits ashore, when the necessary delays of a river journey in those days stopped the progress of the mission to Ava. Otherwise that acute and careful observer would have been able to give us a more detailed account of the geology of Burma, than that to be found in his notes on the "Geological features of the banks of the Irrawaddi, etc."[1] As it is, Dr. Oldham was obliged to give his observations in the form of a narrative, which, although full of lucid and detailed observations, renders it very difficult to follow the author's opinion as to the division of the groups he has noticed. Dr. Oldham expresses his opinion that the rocks of the area within which the oilfields of Yenangyoung are situated belong to the tertiary system, but probably owing to lack of time he does not go into the subject of the division or correlation of these tertiary beds.

It was not until after the researches of Dr. Blandford, Mr. Fedden and Mr. Theobald in Lower Burma, that anything like a sub-division of the tertiary system was attempted. Mr. Theobald, who has embodied the results of his own researches and those of his two colleagues in his interesting memoir on the Geology of Pegu,[2] proposes the following sub-division for the Tertiary rocks of Lower Burma:—

Younger Tertiary	Fossilwood group.
	Pegu group.
Older Tertiary	Nummulitic group.

Of these the Nummulitic group is considered as correlative with the Eocene of Europe, while the Pegu group represents the Miocene; the "Fossil wood group" represents the Pliocene, but Mr. Theobald leaves it an open question as to whether strata of probably Post-Pliocene age are not perhaps also represented in the "Fossil wood group."

We shall presently see that Mr. Theobald has quite correctly recognized the principal divisions of the tertiary rocks in Burma, and although he may have failed in the accurate delimitation of these groups, it is well to state at once that these three sub-divisions are also recognizable in Upper Burma. Where Mr. Theobald's division is chiefly defective is with regard to the Lower Tertiary. Subsequent researches have proved that the "Axial group" (which Mr. Theobald has, on the

[1] Yule: Narrative of a mission to the Court of Ava in 1855. Appendix A, *p.* 307.
[2] Memoirs of the Geological Survey of India, Vol. X.

strength of a misinterpreted fossil, regarded as of Triassic age) must either be included in the tertiary system, of which it represents the lowest division; or might probably form the highest beds of the cretaceous system. Now, anyone acquainted with the country in which the "Axial" formation is chiefly developed, will readily understand the difficulty of accurate observation in such a jungly country as the Arrakan Yoma. In fact, the question of the age of the "Axial group" is not quite settled yet. All we know is that it does not belong to the Triassic system: this may be considered as certain, but whether it represents the lowest tertiary or the topmost cretaceous strata, is a question which still requires careful investigation. In the following pages I have provisionally accepted the view of the tertiary age of the "Axial group," but I wish to state at once that by no means do I consider this question as decided.

The same applies to Mr. Theobald's Negrais rocks, which are probably only metamorphosed Eocene beds. But not having seen these beds I am unable to express my views as to their appearance.

Mr. Theobald has sub-divided both the Pegu and the Fossil wood groups, the first into two, the second into three sub-divisions; but none of these can, to judge from our present experience, claim more than a local importance.

In the following division of the Tertiary rocks in Burma, I have attempted to combine Mr. Theobald's observations with my own in Upper Burma, and I trust that I may have at least succeeded in fixing the outlines of groups therein represented. But years and years of patient labour will elapse before we can arrive at anything like a definite idea of the finer details. If in the following pages the Upper Tertiary is more explicitly dealt with, this is not because it is of much more importance than the Lower Tertiary, but because my work brought me chiefly in touch with the Upper Tertiary.

DIVISION OF THE TERTIARY ROCKS OF UPPER BURMA.

Wherever a complete series of the tertiary beds is developed in Upper Burma, we can, with the greatest ease, recognize and distinguish two groups, which differ widely in the character of the fauna they contain.

The lower group is characterised by a *marine* fauna, which is entirely free from any terrestrial or fluviatile elements in the lower part, but locally shows a slight foreign element by the admixture of rolled fragments of terrestrial animals in its upper beds.

The upper group contains chiefly remains of *terrestrial* animals, mixed with such forms as, according to the habits of their present representatives, must have led an *aquatic* life.

Hand in hand with this wide difference in the palæontological characters goes a distinct change in the features of the sediments. Dark bluish and grey colours characterise those of the lower, and yellow, olive-green and red those of the upper group.

Notwithstanding this wide difference between the two groups, it seems as if the upper rests conformably on the lower, although there exist no passage beds between the two,—a fact which must not be overlooked. I therefore divide the Burma tertiaries into two sub-divisions, *viz*:—

2. Upper Tertiaries or Burma series.
1. Lower Tertiaries or Arrakan series.

For the lower division I suggest the name of *Arrakan series*, owing to its chief development in the Arrakan Yoma; the upper one may be called the *Burma series*, because it is chiefly developed in the broad depression between Arrakan Yoma in the west and Shan hills in the east, which forms the country of Burma proper.

I. ARRAKAN SERIES.

The Arrakan series can again be sub-divided into three groups, which palæontologically, as well as lithologically exhibit considerable differences.

The lowest of these groups is very little known; in fact, we may say we know nothing with regard to its palæontological features.

The middle group is characterised by the abundance of *Nummulites*; while the chief feature of the upper group is the total absence of this genus. Lithologically the two lower groups are characterised by shales and limestones, while, in the upper, sandstones predominate to the nearly total exclusion of other rocks. For the lowest group I suggest the name *Chin division*, while for the middle and upper one Mr. Theobald's names *Nummulitic division* and *Pegu division* may be retained.

1. THE CHIN DIVISION.

Only the bare outlines of the features of this group can be laid down up to the present, it being one of the least known members of the Burma tertiaries. I am nearly certain that subsequent discoveries will essentially modify the views here expressed. So far as I am able to say for the present, the following are the features of this group.

Lithologically, flysch-like shales, and hard limestones are the predominating rocks. It seems as if the shales almost exclusively occupied the lower part of the group, and were followed by the limestones.

Not even the approximate thickness of the shales can be given, but it may safely be supposed that it was considerable. So far as it is known, the central part of the Arrakan Yoma is chiefly built up of these shales, where they form, particularly in the Chin country, numerous parallel ridges rising to over 7,000 feet above sea level. No fossils have been discovered for the present in these shales, but this by no means proves that they are unfossiliferous.

Mr. Theobald's so-called "Axial group" of the southern part of the Arrakan Yoma, which he considered of Triassic age, represents in a broad sense these shales, and it is chiefly due to the observations of Mr. Griesbach, who examined a part of the Arrakan Yoma, where the Axial group was supposed to be present, that we know that it belongs to the tertiary system, and probably forms its lowest part. It requires, however, a long and careful examination before more can be said about the Chin-shales, an examination which will be extremely difficult in a country like the Arrakan Yoma, which is covered with almost impenetrable virgin forest.

2. THE NUMMULITIC DIVISION.

We know a little more about the middle part of the Arrakan series, although this knowledge is very scanty. According to Mr. Theobald, the total thickness of the *Nummulitic* or *Eocene group*, as he calls this subdivision, is 1,223 feet, but to judge from the table given on page 100 of his Memoir, it is quite certain that he has included at least 227 feet more, probably about 500 feet of shales, which probably should be included in the Chin shales. However, this is a matter which can only be decided by actual observation in the field.

According to Mr. Theobald, the lower part of the nummulitic division consists of shales and sandstones, occasionally fossiliferous, capped by a bed of highly fossiliferous nummulitic limestone, of only 10 feet in thickness.

Although I have no doubt as to the correctness of this observation, it is quite certain that in a northern direction the limestone increases in thickness and importance, at the expense of the arenaceous beds. However, this is a matter which must be left to the future to decide.

The fauna discovered in this group, for which we may for the present retain the name *Nummulitic* division, is a rich one, but we know absolutely nothing as to its relationship, because owing to more pressing work, none of my predecessors have undertaken the task of studying it. All that we know at present is that it contains numerous species of the genus *Nummulites*, and, in a bed which most probably belongs to the upper part of the series, the well-known Eocene species, *Velates schmideliana*, Chem. sp. As I have pointed out in the paper, in which I described the occurrence of this species, [1] we may infer from the limited vertical distribution of this species, not only in Europe, but also in Western India, that the stratum in which it was found in Burma belongs to the Eocene system, and must most probably be considered as correlative to the Khirthar group of Western India.

The occurrence of the genus *Nummulites* together with the typical Eocene species, *Velates schmideliana*, Chemn. sp., leaves, therefore, not the slightest doubt that this part of the Arrakan series must be considered as of Eocene age, having in the Khirthar group its correlative in Western India. The lower Tertiaries would therefore be subdivided as follows:—

1. Upper Eocene: *Nummulitic* division.
   Shales and limestones containing a rich fauna of typical eocene forms,
2. Lower Eocene (?): *Chin shales*.
   Shales predominate and have not yielded any fossils up to the present time.

As regards the distribution of the two sub-divisions of the Eocene rocks in Burma it is practically such that the Chin-shales cover a much wider area than the nummulitic division, which, so far as our present knowledge goes, forms only a comparatively narrow band along the outskirts of the Arrakan Yoma.

In conclusion, however, I wish particularly to point out that all that I have said above regarding the subdivision of the Lower Arrakan series must be considered as preliminary. I myself have only very rarely had occasion to observe it, and the above remarks are chiefly based on Mr. Theobald's observations, as they appear in the light of the later researches, particularly those by Mr. Griesbach and myself. I need hardly add that it will require years and years of careful labour in the field, as well as in the museum, before we arrive at anything like a clear conception of the development of the Eocene rocks in Burma.

3. The Pegu division.

The name "Pegu group" was proposed by Mr. Theobald "for a very important

1 Records, Geological Survey of India, 1894, vol. xxvii, page 103.

series of beds intervening between the Eocene or nummulitic division on the one hand, and the fossil wood division on the other."

The above definition of the Pegu division would be a very clear and concise one, if Mr. Theobald had more accurately defined the lower boundary of his "fossil wood group." As it is, the boundaries of the "fossil wood group" are very uncertain and thus the upper limit of the Pegu division is very ill-defined.

I propose to apply the name of Pegu division to that series of beds, which are between the Eocene rocks—characterised by their peculiar marine fauna—and the Irrawaddi division—characterised by its peculiar terrestrial fauna.

In the above definition, the Pegu division constitutes a very well circumscribed series of beds, which are characterised as follows :—

The fauna is of a marine type throughout, but the genus Nummulites is entirely absent. Towards the upper limit rolled fragments of terrestrial animals are, in one place at least, mixed with a purely marine fauna; lithologically, sandstones of pepper and salt colour are predominant, while blue clays are more subordinate.

The above features are so well defined wherever the Pegu-division occurs in Upper Burma, that it is not easy to mistake it, although it varies locally a good deal, as may be expected in a series chiefly composed of sandstones and clays; so that it is frequently very difficult to correlate the local developments of the Pegu division at different localities in Burma. In fact the local developments differ so widely that even at places close to each other, such as Minbu, Yenangyoung, Yenangyat it is extremely difficult, if not impossible, to correlate the single strata composing the sections at the different localities. The difficulty increases of course with the distance, and years will lapse before the relations of this division in Lower and Upper Burma are sufficiently studied. We know, however, for the present enough of the development of this group to enable us to give some more details. The Pegu division may be conveniently separated into two sub-divisions, for the lower of which I propose the name of *Prome stage* owing to its chief development in the neighbourhood of that town, while for the upper one the name of *Yenang-young stage* is suggested.

A.—Prome Stage.

a. Thickness.

Mr. Theobald describes a section of this stage near Prome, measuring 1,950 feet in thickness; but he adds that this apparently does not represent the total thickness. Although, if I interpret his views correctly, he does not think that the total thickness is very much greater.

At Yenangyoung the drill has gone through rocks of the Prome stage up to a depth of 1,000 feet without apparently touching their base.

At Yenangyat it is known partly by surface outcrops, partly by borings, to have a thickness of not less than 1,100 feet.

On the right bank of the Chindwin between the Kale and Yu river, I estimated its thickness at about 5,100 feet. In this part of the country I must have been pretty close to the base, although the actual contact between the upper Eocene and the lower beds of the Prome stage was not observed, but numerous pebbles containing Eocene fossils indicated the proximity of the Eocene beds.

If therefore we estimate the total thickness of the Prome stage at something like 5,000 feet, I think we shall not be very far off the mark

b. Lithological characters.

The chief constituents of the Prome stage are sandstones and clays, the latter are however much subordinate to the former; still more subordinate are coal seams and ferruginous clays; locally the sandstones contain petroleum, and, at isolated places, the fossil resin, burmite. The sandstone is very uniform in character, it is finely grained, of a greyish colour, which may best be styled "pepper and salt colour." Sometimes the sandstone is very soft, other beds are more siliceous, and therefore harder. When exposed, these beds disintegrate into rather regular lumps, which retain for a long time their original position, before they fall to pieces. Such beds which resemble the pavement, may frequently be seen between Thayetmyo and Prome, or on the Upper Chindwin.

The clay is also of very uniform character, being generally a very tough clunch of bluish colour.

Sandstone and clay alternate in beds of various thickness; frequently, as for instance near Yenangyoung, beds of clay as thin as paper may alternate with similar beds of sandstone, while at other places, as for instance in the Upper Chindwin district, the sandstone forms a continuous bed of several hundred feet in thickness. The clay beds may also attain a considerable thickness, but I never found that they equalled the sandstone in this respect.

The coal seams are generally of small thickness, the thickest known to me is a seam of 10 feet, cropping out in the ravine of the Nantahinchoung in the Upper Chindwin district; generally they are between 1 and 2 feet in thickness. It would exceed the limits of this paper were I to dwell in detail on the occurence of the coal in Upper and Lower Burma; those interested in its occurence will find ample information in the papers cited below.[1]

It seems, however, that in the Chindwin district the coal seams are restricted to the lower part of the Prome stage, but to judge from other localities such as Kabwet, Wuntho or Thayetmyo some seams of inferior quality also occur in the upper parts.

As the occurrence of the petroleum will be dealt with in a special memoir, which will shortly be publisned, it is needless to go into details. All that may be said is, that it appears that the petroleum chiefly occurs in the upper parts of the Prome

[1] Oldham: Memorandum on the coal found near Thayetmyo on the Irrawaddi river, Selections from the Records of the Government of India, Home Department No. X, page 99, 1856. Reprinted in papers on Burma, issued by the Geological Survey.

Oldham, in Yule's Narrative of a Mission to the Court of Ava, Appendix A., page 33?.

Jones: Notes on Upper Burma: Records of the Geological Survey of India, Vol. XX, Part II, 1887, page 185.

Noetling: Memoir on the Upper Chindwin Coal-fields, 1889.

Noetling: Report on the coal-fields in the Northern Shan States: Records of the Geological Survey of India, 1891, Vol. XXIV, page 99.

Noetling: Note on the Geology of Wuntho in Upper Burma: Records, Geological Survey of India, Vol. XXVII, page 119.

stage, but that it is unquestionable that small quantities are also found in the lower parts.

The occurrence of the fossil resin, burmite, the famous amber of Burma, has been described by me in a special paper.[1] Dr. Helm [2] has devoted two papers to the chemical properties of this fossil resin, which, according to him, is distinctly different from the real amber or succinite.[3]

c. Palæontological characters.

Although the rich fauna which Messrs. Theobald and Fedden collected in the Pegu division of Lower Burma still waits to be described, the examination of the fauna discovered in the petroleum-bearing strata of Yenangyat has shed so much light on the age of the Prome stage that we can now classify it definitely in the sequence of the tertiary beds without being obliged to have recourse to an indirect method. The information recently obtained by the deep borings at Yenangyat, has proved that the fauna which I have described [4] from this place comes from the petroliferous sandstone at the top of the Prome stage. The following species have been observed:—

1. *Paracyathus caeruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.
3. *Ostrea sp*
4. *Pecten cf. favrei*, d'Arch & Haime.
5. *Daphoderma cœlata*, Reeve.
6. *Nucula alcocki* Noetling.
7. *Astarte (?) dubia*, Noetling.
8. *Venus cf. scalaris*, Bronn.
9. *Tellina (Tellinella) hilli*, Noetling.
10. *Tellina kingi*, Noetling.
11. *Solen sp.*
12. *Corbula harpa*, d'Arch. & Haime.[5]

[1] On the occurrence of Burmite in Upper Burma: Records, Geological Survey of India, 1893, vol. xxvi, page 31.

[2] Note on a new fossil amber-like resin occurring in Burma: Records, Geological Survey of India, 1892, vol. xxv, page 180

Further Note on Burmite, a new amber-like fossil resin from Upper Burma; Records, Geological Survey of India, 1893, vol. xxvi, page 61.

[3] It may here not be quite out of place to correct a mistake with regard to the age of certain coal seams occurring in Tenasserim. Mr. Oldham in the Manual of India, 2nd edition, page 297, expresses his view, that as the coal contains small nodules of a resinous mineral like amber, these coal seams were of cretaceous age, because in the Assam hills the mineral resin is characteristic of the cretaceous coals. If any inference regarding the age were admissible from the association of fossil resin and coal, it could only be one, and that is that the coal seams are of miocene age, because everywhere in Upper Burma the fossil resin is found in strata belonging to the Prome stage, which is of distinctly miocene age.

[4] Memoirs, Geological Survey of India, vol. XVII, Part I.

[5] It may be remarked here that the species which I determined as *Corbula harpa* d'Archiac and Haime is really different from that species, although this could not be recognised at the time owing to the rather deficient figure of Messrs. d'Archiac and Haime. The recent examination of the *Corbula harpa* d'Arch. and Haime from Sind has proved that notwithstanding the great similarity of the right valve, it materially differs from the Burma species by the sculpture of the left valve; *Corbula harpa* d'Arch. and Haime from Burma must therefore be cancelled, and a new name substituted for it. My remarks on page 4 of the abovenamed memoir, have therefore been fully borne out by the facts, and one anomaly of the otherwise truly miocene fauna has disappeared.

13. *Trochus buddha*, Noetling.
14. *Trochus blanfordi*, Noetling.
15. *Solarium affine*. Sow.
16. *Discohelix minuta*, Noetling.
17. *Turritella affinis*, d'Arch. & Haime.
18. *Siliquaria sp.*
19. *Calyptraea rugosa*, Noetling.
20. *Natica obscura*, Sow.
21. *Natica callosa*, Sow.
22. *Sigaretus cf. bicostatus*, Sow.
23. *Aporrhais* sp.
24. *Cypræa granti*, d'Arch. & Haime.
25. *Trivia smithi*, K. Martin.
26. *Cassidaria dubia*, Noetling.
27. *Cassidaria minbuensis*, Noetling.
28. *Ficula theobaldi*, Noetling.
29. *Triton pardalis*, Noetling.
30. *Ranella tubercularis*, Lamark.
31. *Nassa cautleyi*, d'Arch & Haime.
32. *Clavella djocdjocartæ*, K. Martin.
33. *Fasciolaria nodoulsa*, Sowerby
34. *Fasciolaria feddeni*, Noetling.
35. *Murex (Muricidea)* sp.
36. *Murex tschihatscheffi*, d'Arch & Haime.
37. *Murex arrakanensis*. Noetling.
38. *Voluta dentata*, Sowerby.
39. *Oliva djocdjocartæ* K. Martin.
40. *Cancellaria cancellata*. Lam.
41. *Rapana* sp.
42. *Terebra fuscata*, Brocchi.
43. *Pleurotoma (Drillia) interrupta*, Lamark.
44. *Pleurotoma yenanensis*, Noetling.
45. *Conus (Rhizoconus) mallacanus*, Hwass.
46. *Conus (Leptoconus) marginatus*, Sowerby.
47. *Balanus sublaevis*, Sowerby.
48. *Callianassa* sp.
49. *Pagurus* sp.
50. *Lamna* sp.
51. *Galeocerdo* sp.
52. *Carcharias (Prionodon)* sp

Out of a total of 52 species, 48 were specifically determined, but among these there are three species which could only be, with some doubt, referred to previously known species. There remain therefore 38 species, which are sufficiently well determined to allow of geological conclusions being drawn from them. Out of these 38 species, 15 have been recognized as new, while the balance of 23 species could be identified with species previously described, but as the species referred to *Corbula harpa*, from western India, cannot be considered as identical with this species, the figures therefore now stand as follows :—

New species . . .	16
Previously described species	22

The geological distribution of these 22 species is as follows :—

Recent, but not previously known in fossil state.

1. *Paracyathus cæruleus*, Duncan.
2. *Eupsammia regalis*, Alcock.

Nari group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch, and Haime).
2. *Solarium affine*, Sowerby.
3. *Turritella affinis*, Sow.
4. *Cypræa granti*, d'Arch. & Haime.
5. *Voluta dentata*, Sowerby.

Gaj group—

1. *Daphoderma cælata*, Reeve (*Arca burnesi*, d'Arch. & Haime).
2. *Natica obcsura*, Sow.
3. *Nassa cautleyi*, d'Arch. & Haime.
4. *Balanus sublævis*, Sow.

Older Tertiary—

1. *Daphoderma cælata*, Reeve.
2. *Fasciolaria nodulosa* Sowerby.

Of uncertain horizon are—

1. *Natica callosa*, Sowerby.
2. *Murex tschihatscheffi*, d'Arch. & Haime.
3. *Conus* (*Leptoconus*) *marginatus*, Sow.

In the Miocene of Java have been found—

1. *Trivia smithi*, K. Martin.
2. *Clavella djocdjocartæ*, K. Martin.
3. *Oliva djocdjocartæ*, K. Martin.
4. *Cancellaria cancellata*, Lam.
5. *Pleurotoma interrupta*, Lam.
6. *Conus* (*Rhizoconus*) *mallacanus*, Hwass.

From the above list it is evident that the fauna cannot be older than of Miocene age: only two species could be identified, which occur in the older tertiary beds of India: one of these, however, also ascends into higher groups, in fact, it is still living in the Indian Ocean. The geological horizon of three species is unknown, and we may therefore disregard them for the moment. Out of the remaining species—

Two are recent and not previously known in a fossil state.
Five range from the Miocene to the present day.
Three have been found in the Miocene of Java.
Four have been found in the Nari group of Western India.
Three have been found in the Gaj group of Western India.

As out of a total of 17 species, 7, that is to say nearly 50% are still living, we are therefore justified in assuming a miocene age for the beds which have yielded this fauna. It only remains to be seen whether the fauna bears a greater resemblance to the Gaj or to the Nari group of Western India. The evidence in this regard is very meagre, in fact it would be rather rash to form a final conclusion, but from the fact that the species from Java have been found in beds which are considered as of the same age as the Gaj group, I feel inclined to consider the fauna of the Prome stage as correlative to the Gaj group of Western India.

d. Facial development of the Prome stage.

In studying the development of this stage, particularly in Upper Burma, it is at once obvious that, notwithstanding the purely marine character of the fauna, some beds, which must be considered as homotaxial to the former, were either deposited in estuaries or at no great distance from the coast.

For instance, at Yenangyoung, a well, which had reached a depth of 156 feet from the surface, and which had, in the light of the information recently obtained, passed through the 1st and 2nd petroliferous sands, a highly fossiliferous conglomerate of about 6 inches in thickness was discovered in which I collected the following species :—

1. *Corallium, gen. div*; one closely related to *Paracyathus cæruleus, Dunc.*
2. *Teredo* sp.
3. *Venus* sp.
4. *Cardium* sp.
5. *Arca* sp.
6. *Pecten* cf. *favrei*, d'Arch & Haime.
7. *Gastropoda, gen. div.*

The invertebrata are all very ill-preserved, in fact they are either only casts or moulds, the calcareous substance of the shell being entirely destroyed by sulphuric acid, which is represented by a large quantity of iron pyrites. The latter makes the preservation of these fossils almost impossible: notwithstanding repeated coatings of varnish, they have, in the damp climate of Calcutta, almost entirely crumbled to pieces with considerable efflorescence. The vertebrata have yielded the following list :—

1. *Teleostei* gen. div.
2. *Myliobatis* sp.
3. *Odontaspis* sp.
4. *Carcharias* sp.
5. *Chelonian* bones.
6. *Crocodilis* sp.
7. *Antelope* sp. (?)
8. *Anthracotherium silistrense.*
9. *Rhinoceros* or *Hippopotamus* sp.

Besides the abovenamed forms which could be recognized with certainty, the conglomerate contained numerous fragments of bones, which have been too much rolled to be determined. The chief interest however rests with the fact, that fragments of terrestrial and estuarine forms are mixed with a purely marine fauna, and that such a strangely composed fauna has been found in strata between the 2nd and 3rd oil-sand at Yenangyoung.

On the other hand, the petroliferous sand of Yenangyat, which is perhaps a little higher in the series, has yielded the purely marine fauna above described.

In the Upper Chindwin district the coal-seams in the lower part of the Pegu division apparently indicate an estuarine, or at least a littoral deposit, while further south near Thayetmyo, a purely marine fauna is found in the lower portion of the Prome stage. It seems to me, therefore, that not only are beds, which are undoubtedly homotaxial, partly marine and partly of littoral or of estuarine character, but that also owing to local oscillations these changes take place in a vertical direction. On the whole it may, however, be said that the marine character is more pronounced in Lower Burma, while the littoral or estuarine formation prevails in Upper Burma. This view, however, by no means affects the opinion expressed above as to the wide difference between the fauna of the Prome stage and that of the Irrawaddi division, nor does it modify the conclusions based thereon with regard to the sub-division of the Burma tertiaries.

e. Sub-division of the Prome stage.

It is obvious that, under the circumstances above described, a general sub-division of the Prome stage is extremely difficult, and that those attempts, which have so far been made by Mr. Theobald in Lower Burma, and by myself in the Upper Chindwin district are of purely local value, hardly holding good for more than a few miles around the locality for which they were made.

Under these circumstances it would be superfluous to repeat them here. All that can be said is that, perhaps, after years of careful study, and after an exhaustive examination of the fauna, and a most careful determination of the fossiliferous horizons in the sequence of the series, it will, perhaps, be possible to arrive at a general sub-division of the Prome stage; for the present we must be satisfied with local sub-divisions, without making any attempt at correlating their individual members.

B.—The Yenangyoung stage.

A marked lithological difference distinguishes the overlying series of beds from the Prome stage. No sharper boundary can be imagined than the contrast between the bluish tinges of the Prome stage, and the brown or olive-coloured beds of the Yenangyoung stage at places where the contact between the two is well exposed, as for instance in the Oung-Ban ravine between Kodoung and Twingon. In fact, the results of the deep borings carried out at Twingon render it utterly impossible to assume an absolutely conformable superposition of the Yenangyoung stage on the Prome stage. The study of these sections leads to the assumption that a break must exist between the Upper Prome beds and the lower beds of the Yenangyoung stage, at least in the country near Yenangyoung. On the other hand it deserves to be mentioned that at Yenangyat the Yenangyoung beds rest (apparently with absolute conformity) on the Prome stage.

Although there exists, therefore, a sharp lithological difference between the Prome stage and the Yenangyoung stage—a difference from which one would rather feel inclined to consider the latter as the basal beds of the Irrawaddi division, so great is the lithological similarity between the two—still the palæontological evidence unquestionably proves that the Yenangyoung stage is widely different from the Irrawaddi division and closely related to the Prome stage. It must therefore be included in one series with it.

a. Thickness.

At Yenangyoung the beds composing the Yenangyoung stage form a series of about 1,100 feet in thickness.

At Singu the thickness is about 700 feet, but here the whole series is not completely exposed, and it is impossible to say to what depth it may still extend.

At Yenangyat the whole series is again well seen; its thickness at this place is about 1,200 feet.

It is therefore tolerably certain that, at least in Central Burma, the Yenangyoung stage is only of moderate thickness as compared with the other groups composing the Burma tertiaries.

b. Lithological characters.

The chief constituents of the Yenangyoung stage are soft clays, alternating with beds of sandstone, which may either form thin hard bands, or thicker soft beds. The clay is usually of olive colour, but in various instances, bluish tinges, particularly near Yenangyat, have been observed. One involuntarily imagines a struggle between the bluish colour of the older beds and the olive colour of the newer strata; there are frequent relapses, so to speak, to the original bluish colour, till eventually the olive colour gets the upper hand and bluish tinges have entirely disappeared in the Irrawaddi division. This struggle between the two colours is extremely well seen at Yenangyat, where, after having made a final effort, the bluish colour of the clay disappears with the highest bed of the Yenangyoung stage. The sandstone is usually very friable, and of a yellowish colour; bands of hard kidney-shaped or globular concretions occurring very frequently.

A most remarkable feature is the presence of gypsum, which occurs frequently in large crystals in the clayey beds. It is noticeable that no gypsum is found either in the lower Prome stage or in the Upper Irrawaddi division, and in this respect its occurrence forms an exceedingly useful feature for the recognition of the Yenangyoung stage. One may be almost certain to have beds of the Yenangyoung stage under observation when the gypsum is noticed.

c. Palæontological characters.

Fossils are rather scarce in the Yenangoung stage, that is to say, the localities in which they are found are not numerous; but when present the fauna is usually a rich one. So far I have discovered three places where fossils have been found, and every one of these localities unquestionably represents a different horizon.

The lowest horizon is probably represented by beds which contain a very rich fauna near Minbu. In a similar horizion, fossils also occur at Yenangyat, but I never found at this place a bed where they were recognizable, being in every case mostly fragments.

Next in the series follows the *Cypricardia* bed of Singu.

The last in the series is the *Batissa* or *Cyrena* bed containing countless numbers of the two species *Batissa* (*Cyrena*) *crawfurdi* and *petrolei.* It will be useful to discuss the palæontological characters of each of these beds separately, and eventually compare the whole of the fauna with that of the Prome stage.

1. MINBU-BED.

The fauna of this bed, which is well exposed at the hill, north of the mud-volcanoes, has been described by me in the memoir previously quoted. So far the following species have been found:—

1. *Paracyathus cæruleus*, Duncan.
2. *Ostrea*, sp. 1.

3. *Pecten* cf. *favrei*, d'Arch. & Haime.
4. *Nucula alcocki*, Noetling.
5. *Venus* sp.
6. *Tellina kingi*, Noetling.
7. *Corbula* spec. nov.[1]
8. *Trochus buddha*, Noetling.
9. *Trochus blanfordi*, Noetling.
10. *Solarium affine*, Sowerby.
11. *Solarium cyclostomum*, Menke.
12. *Scalaria birmanica*, Noetling.
13. *Scalaria irregularis*, Noetling.
14. *Scalaria subtenuilamella*, d'Arch. & Haime.
15. *Turritella affinis*, d'Arch. & Haime.
16. *Calyptræa rugosa*, Noetling.
17. *Natica obscura*, Sowerby.
18. *Natica callosa*, Sowerby.
19. *Cerithium* sp.
20. *Strombus nodosus*, Sowerby.
21. *Cypræa granti*, d' Arch. and Haime.
22. *Cassis d' archiaci*, Noetling.
23. *Cassidaria dubia*, Noetling.
24. *Cassidaria minbuensis*, Noetling.
25. *Triton* (*Simpulum*) *davidsoni*, d'Arch. & Haime.
26. *Triton pardalis*, Noetling.
27. *Ranella tubercularis*, Lamark.
28. *Nassa cautleyi*, d' Arch. & Haime.
29. *Clavella djocdjocartæ*, K. Martin.
30. *Fasciolaria nodulosa*, Sowerby.
31. *Murex arrakanensis*, Noetling.
32. *Volvaria birmanica*, Noetling.
33. *Voluta dentata*, Sowerby.
34. *Oliva djocdjocartæ*, Martin.
35. *Terebra fuscata*, Brocchi.
36. *Pleurotoma voysi*, d'Arch. & Haime.
37. *Pleurotoma* (*Drillia*) *interrupta*, Lamark.
38. *Pleurotoma yenanensis*, Noetling.
39. *Conus* (*Rhizoconus*) *mallucanus*, Hwass.
40. *Balanus sublaevis*, Sowerby.
41. *Callianassa* sp.
42. *Lamna* sp.
43. *Myliobates* sp.
44. *Carcharias* (*Prionodon*) sp

The above list shows that the Minbu bed contains nearly the same number of species as the Prome beds and that out of a total of 44 species it contains 29 species which are common to both faunas. So far the forms peculiar to the Minbu bed are the following :—

1. *Ostrea* sp. 1.
2. *Venus* sp.
3. *Solarium cylostomum*, Menke.
4. *Scalaria birmanica*, Noetling.
5. " *irregularis*, Noetling.
6. " *subtenuilamella*, d' Arch. & Haime.

[1] Described as *Corbula harpa*, d'Arch. & Haime.

7. *Cerithium* sp.
8. *Strombus nodosus*, Sowerby.
9. *Cassis d'archiaci*, Noetling.
10. *Triton (Simpulum) davidsoni*, d'Arch. & Haime.
11. *Triton pardalis*, Noetling.
12. *Volvaria birmanica*, Noetling.
13. *Terebra fuscata*, Brocchi.
14. *Pleurotoma voyesi*, d' Arch. & Haime.
15. *Myliobates*, sp.

Of these 15 species 4 have been only generally determined, 4 are new forms and the remainder of 5 species have been previously described. Of these the following three species are found in the Gaj group :—

Scalaria subtenuilamella, d'Arch. & Haime.
Strombus nodosus, Sowerby.
Triton (Simpulum) davidsoni, d'Arch. & Haime.

in the Nari group occur—

Solarium cyclostomum, Menke.
Triton davidsoni, d' Arch. & Haime.

recent is—

Solarium affine, Menke.

of uncertain geological horizon is—

Pleurotoma voyesi, d'Arch. & Haime.

while the last one—

Terebra fuscata, Brocchi.

occurs in the Upper Miocene of Europe.

I do not think that the above meagre list is in itself sufficient to decide the question of the age of the Minbu bed; if any inference could be drawn, it would be that it shows almost a larger number of species found in the Gaj group of Western India than the Yenangyat fauna. It may, perhaps, be possible that its actual horizon is a little lower down in the series than I have here assumed, and that it ought to be included in the Prome stage, although this would not materially alter the views here promulgated regarding the position and age of the Yenangyoung stage. I have assumed from its position in the series above the petroliferous horizon, which, so far as we know for the present, seems to be a very excellent one, that it is younger than the Yenangyat fauna; but of course it is extremely difficult, owing to the monotonous development of the tertiary strata, absolutely to correlate certain beds of two localities, which are at some distance from each other.

That there exists a difference between the two faunas cannot be denied, if we look through the above list; this difference may only represent the local variation of one and the same fauna, or it may really represent a difference in the geological age of the two faunas. For the present this question must be left undecided, as our imperfect knowledge of the tertiary fauna in Burma does not allow such intricate questions as the above to be settled; but my opinion is, that the Minbu fauna holds a position at the base of the Yenangyoung stage, and I have therefore included it in the discussion of this group. Should it, however, eventually be found better to include the Minbu-bed in the Prome stage, it must not be disregarded, that it certainly occupies a higher horizon than the Yenangyat beds.

2. *Cypricardia*-BED.

The geological position of this bed is much more accurately fixed with regard to the Yenangyat bed, than that of the Minbu bed. The Yenangyoung stage has been traced from Yenangyat down to Singu, and it is quite certain that at Singu only the higher beds of the Yenangyoung stage are exposed.

The Cypricardia bed holds a position comparatively close to the upper boundary of the Yenangyoung stage, and it must therefore be decidedly younger than either the Minbu or Yenangyat fauna. It is an argillaceous sandstone containing numerous lumps of hard clay, which, strange to say, are almost in every case perfectly riddled by the borings of a *Lithodomus*. Its thickness is not more than 6 inches, but it forms a most constant horizon, which can be easily recognized at either side of the anticline. It is probably from this bed that the late Dr. Oldham obtained some fossils, when visiting Singu in 1855.[1] Unfortunately this fauna has not been carefully examined yet, because it was only during the field season 1894-95, that I discovered the *Cypricardia* bed, but still the knowledge of the species occuring in the Yenangyat and Minbu beds has enabled me to identify some of the species occurring in it, while other forms were recognised as being absent in the abovenamed beds. The entire character of the fauna of the *Cypricardia* bed is totally different from that of either the Yenangyat or Minbu beds. While in the former the *Gastropoda* predominate—out of a total of 69 species, 45 belonging to the *Gastropoda*—it is certain that in the Cypricardia bed the *Pelecypoda* predominate not only by number of species, but also by number of individuals. The commonest forms are an *Ostrea* sp., *Pecten cf. favrei* d'Arch. and Haime, and a *Cypricardia*, besides *Paracyathus cæruleus*, Duncan. It is, however, strange that, although the *Ostrea* sp. is the commonest form, not a single well-preserved specimen could be obtained. *Pecten cf. favrei*, d'Arch. and Haime, is always well-preserved like the other Pelecypoda, and I dare say that the question whether it really represents the Indian species can now be settled; next in frequency is a beautifully preserved *Cypricardia*, and an *Avicula*, and then comes the easily recognizable *Paracyathus cæruleus*, Duncan. The following is a provisional list of the fossils, which I have been able to recognize; but I wish at once to state that this list is by no means exhaustive.

1. *Paracyathus cæruleus*, Duncan, very common.
2. *Ostrea*, sp. apparently related to *Ostrea*, sp. 1, from Minbu: very common.
3. *Pecten cf. favrei*, d'Arch. and Haime, very common.
4. *Modiola*, sp. 1, rare.
5. *Modiola*, sp. 2, rare.
6. *Lithodomus* sp., very common.
7. *Avicula* sp., very common.
8. *Daphoderma caelata*, Reeve (*Arca burnesi*, d'Arch. and Haime; common).
9. *Venus*, sp. 1, the same as found at Minbu; very common.
10. *Venus*, sp. 2, rare.
11. *Tellina* (*Tellinella*) *hilli*, Noetling; rare.
12. *Tellina kingi*, Noetling; always beautifully preserved, but not common.
13. *Trochus sp.*, *cf. blanfordi*, Noetling; common.
14. *Solarium affine*, Sow.; rare.

[1] Yule, mission to the Court of Ava, p. 27, and Appendix A, page. 319.

15. *Conus (Rhizoconus) mallacanus*, Hwass; rare.
16. *Conus (Leptoconus) marginatus*, Sowerby; rare.
17. *Callianassa* sp. nov. The hands of a gigantic *Callianassa* sp. are not very rare.

To judge from this specimen it seems that the isolated fragment of a finger which I referred to *Pagurush*[1] really belongs to this gigantic *Callianassa*. As I have remarked above, this list is by no means an exhaustive one, and a careful examination of my collection will swell its number considerably; but it may be stated at once, that almost all the forms, which have been recognized hitherto, are identical with those described from the Yenangyat and Minbu beds. On the other hand some new forms, which had hitherto not been found in either of the abovenamed beds, have been discovered; the most conspicuous among these are—

Avicula sp.
Cypricardia sp.

besides various others.[2]

The geological horizon of the *Cypricardia* bed being decidedly higher up in the series than either of the fauna abovementioned, it is almost certain that the faunistic difference noted cannot be considered as only a local variation.

3. *Batissa-(Cyrena-)* BED.

The highest position in the Yenangyoung stage is occupied by a bed which is unfossiliferous almost throughout its whole extent, but containing at two places at least in the neighbourhood of Minlindoung, countless numbers of *Batissa crawfurdi* Noetling and *Batissa petrolei* Noetling. These two forms are also found in the next higher bed, which most decidedly belongs to the Irrawaddi division, and they form the connecting link with that series of strata which contain such an entirely different fauna from that of the older tertiaries.

If the *Cytherea promensis*, a species established by Mr. Theobald, but neither described nor figured, is, as I suppose, identical with either *Batissa crawfurdi* Noetling or *Batissa petrolei*, Noetling, we are bound to assume that this form occurs far down in the tertiary series of Lower Burma. The question is an interesting one, but it can only be decided after the examination of Mr. Theobald's collections. In Upper Burma the *Batissa* bed concludes the Yenangyoung stage, and if we assume that this horizon would be the same in Lower Burma, the logical consequence would be that the Yenangyoung stage is much thicker in Lower Burma and that on the top of the *Batissa* bed there exist several fossiliferous horizons, which are not represented in Upper Burma.

These are, however, views which can only be settled by actual observation in the field, as I do not think that the examination of Mr. Theobald's collections will shed much light on this question, as the positions of the horizons in which the fossils were collected are not always known with certainty with reference to each other.

I may conclude the description of the palæontological features of the Yenangyoung stage with the remark that, to my knowledge, no fossil wood either car-

[1] Memoir, Geological Survey of India, Vol. XXVII, part. I, page 44.
[2] I hope that I shall soon be able to give an exhaustive description of this fauna which, from its geological position, has a particular interest.

bonised or silicified has been discovered in it. The absence may be accidental, but it seems significant to me that hitherto no silicified wood has been found in either group.

c. *Distribution of the Yenangyoung stage.*

The Yenangyoung stage being established as the series of strata intermediate between the Prome stage and the fossil wood group (Irrawaddi division) in Upper Burma, nothing can be said with regard to its distribution in Lower Burma; but it is almost certain that it is also represented in that part, although it seems that it does not form such a well circumscribed series as in Upper Burma. In fact it seems that in Lower Burma it merges more or less into the Prome stage.

In Upper Burma it is well represented near Minbu, at Yenangyoung, Singu and Yenangyat, but it must be kept in mind that the localities where it is well exposed, are comparatively speaking of limited extent, as it appears near the surface only where the conditions have been favourable; and in almost the whole of Upper Burma it remains hidden beneath the overlying Irrawaddi division.

I am not quite certain whether the Yenangyoung stage is represented in the Chindwin hills; it is most probably represented, but it does not seem to form such a conspicuous member in the series. It is, perhaps, possible that part of the sandstone beds, which to a thickness of approximately 6,000 feet overlie the Prome stage, represent the Yenangyoung stage, but with regard to this we must await the result of further examination.

II.—THE IRRAWADDI DIVISION.

The Irrawaddi division comprises, broadly speaking, Mr. Theobald's fossil wood group, and I have therefore to explain why I changed the name and substituted a new term for Mr. Theobald's designation. The chief reason is, that "Fossil wood group" is by no means an appropriate term for this series. Not only are numerous beds, particularly in the lower part of the series utterly destitute of fossil wood, but what is much more important certain post-tertiary beds abound in fossil wood. In fact, one would rather feel inclined to apply the term "fossil wood group" to some diluvial gravel beds, so full are the latter sometimes of enormous pieces of fossil wood. For this reason these post-tertiary gravels have frequently been mistaken for tertiary strata, and, in order to avoid any confusion, I preferred a different name, and have therefore chosen the name Irrawaddi division from the enormous development attained by these beds in Upper Burma in the basin of the Irrawaddi.[1]

a. *Thickness.*

I include in the Irrawaddi division all the beds above the Yenangyoung stage which are characterised by the remains of terrestrial and fluviatile animals but below the unconformity which separates the post-tertiary beds from those of tertiary age.

The Irrawaddi division, as thus circumscribed, exhibits a measured thickness of 4,620 feet in the neighbourhood of Yenangyoung, but it is quite certain that this does not by any means represent the total thickness of the division.

[1] In previous papers I used the term Irrawaddi sandstone to designate this group on account of the preponderance of yellow sandstones, but I think that the term Irrawaddi division would be preferable.

The cross-cut of the Irrawaddi bed between Singu and Salemyo affords an exceedingly good section of the Irrawaddi division, from its base to most probably within a short distance of its uppermost beds. The calculated thickness of the Irrawaddi division in this section would be about 20,000 feet. This will probably nearly represent its greatest thickness in Upper Burma, at least in that part of the country which chiefly interests us for the present.

In Lower Burma the Irrawaddi division is apparently much less developed than in Upper Burma. Mr. Theobald gives no figures regarding the total thickness of his "Fossil wood group" but, to judge from his figures, it cannot be anything like that attained in Upper Burma.

b. Lithological characters.

The rocks which compose the Irrawaddi division form by their light colours a most marked contrast to the dark coloured beds of the older strata. Light yellow is the prevailing colour, but dull red, brown and olive-green tinges are by no means rare, although they take only a subordinate rank.

The predominant rock is a very soft sandstone, which might perhaps better be termed "sand-rock" of light yellow colour. It forms thick beds which frequently contain nodular or kidney-shaped concretions of extremely hard siliceous sandstone. These concretions which are sometimes of considerable size, are arranged in strings, parallel to the bedding, and stick out of the surrounding softer material forming a very conspicuous feature in the landscape. Alternating with the sandstone are beds of olive-coloured soft clay, which, however, never attain the thickness of the sandy beds.

Still more subordinate, but very important from a palæontological point of view are dull red bands of a ferruginous conglomerate. Sometimes all foreign matter is so rare that these bands form regular layers of cellular iron ore, which have in former times been used for the production of iron. Their thickness changes from a few inches up to about 15 feet, but it must be mentioned that they do not as a rule seem to form continuous layers, but more or less irregular strings, which although parallel to the bedding, may suddenly die out at one place and re-appear at another. The only exception seems to be the ferruginous conglomerate at the base of the group, which forms a very continuous layer of which I shall presently have more to say.

The composition of these ferruginous conglomerates proves that they must have been formed along a beach, for they exhibit all the flotsam and jetsam which is generally gathered in such places. There are small pieces of drift-wood now changed into hydroxide of iron, small pebbles of quartz and ferruginous clay, rolled fragments of bones, all mixed up, sometimes gathered in small heaps, sometimes spread out and forming only a thin, disconnected layer. A femur of probably *Rhinoceros sp.* which I found in one of these layers affords an exceedingly good illustration regarding the conditions under which they were formed. It rested with one side on a bed of sandstone and around it, and partly over it, were heaped ferruginous clay—pebbles, etc. etc.; now that side on which the bone rested was considerably rubbed, thus indicating the result of the friction on the underlying sand, produced by the gentle rocking of the bone by the waves, while lying on the beach.

The ferruginous conglomerates afford us therefore a material help, with regard to the conditions under which the Irrawaddi division was deposited, and from this point they deserve special attention.

c. Palæontological characters.

The Irrawaddi division is undoubtedly the most interesting in the whole series of the Burma tertiaries owing to the fact that it contains numerous remains of terrestrial and fluviatile animals. It is, however, an open question whether these remains are generally distributed throughout the group, or whether they are restricted to certain localities only. It seems to me that there is no reason why they should not be found anywhere, whenever the strata of this group are exposed, but so far as my experience goes they are much more frequent at certain localities than at others.

For instance, along the river shore from Nyounghla to a few hundred yards north of Sithabwé village fossil bones are extremely common; further north they become scarce, and north of Yenangyoung I have not yet found a single specimen, although the beds developed in this part are the same as those south of Yenangyoung village. Near Pagan I have searched for miles along the bank of the Irrawaddi, where the Irrawaddi division is well exposed, without finding a single specimen.

It is further very remarkable that not only were the first fossil bones which came from Burma, and which were described by Dr. Buckland as early as 1823,[1] collected near Yenangyoung, probably at the very locality which I mentioned above, but that also the chief collection of fossil bones which was made by the members of the Mission to Ava, was found near Yenangyoung.[2] To judge from a remark made by King Mindon Min in the most interesting conversation recorded on pages 112 and 113 of Yule's Mission to Ava, "Biloos" bones[3] are very common in the Yaw country, and it is quite possible that the list which Mr. Theobald gives[4] as coming from "Ava" refers to fossils collected in the Yaw country. They certainly cannot come from Ava, as nowhere in the neighbourhood of that town do beds of the Irrawaddi division occur.

Mr. Theobald expressly states that in Lower Burma the fossil wood group is only locally mammaliferous, and if we thus take all the evidence we must believe that the fossil bones are only of frequent occurrence at certain localities, of which three are known at the present time, *viz.*:—

1. Lema, near Thayetmyo in Lower Burma.
2. Bank of the Irrawaddi between Nyounghla and Yenangyoung.
3. Yaw-country.

Of these three localities, I know only the second from personal experience; as regards the first, we have the evidence of Mr. Theobald, and as regards the third, I must say that all the probabilities are in favour of the occurrence of fossil bones, because the very strata in which they have been found near Yenangyoung are largely developed in the broad valley of the Yaw. On the other hand, I must say that this is no absolute proof, for although the Irrawaddi division is largely developed in Northern Burma, as for instance, in the Pakôkku, Upper Chindwin, Ye-u and Shewbo Districts, yet I have not found a single specimen of a fossil bone, although I repeatedly and carefully searched for them. I may have overlooked them, a possibility which I fully admit, and future researches may discover them in

[1] Transactions of the Geol. Soc., Series II, Volume II, page 377.
[2] Narrative of the Mission to the Court of Ava, 1858, page 315.
[3] Biloo, a fabulous monster.
[4] Op jam. cit., p. 07.

parts where I have looked in vain, but for the present we must content ourselves with stating that the locality in Upper Burma where fossil bones have been found in largest numbers is the country around Yenangyoung.

The seemingly erratic manner of horizontal distribution of the fossil bones might perhaps be explained if we assume that they are restricted to a certain portion of the strata of the Irrawaddi division, and that they are therefore only found at places at which that particular portion is well exposed.

The question is a difficult one to decide, and would require further observations, but if one may be allowed to draw a conclusion from the occurrence of the fossil bones around Yenangyoung it seems that they are restricted to the lower and middle parts of the Irrawaddi division, while they are extremely rare, if not entirely wanting, in the upper part, being replaced by the frequently occurring fossil wood. This supposition would explain the curious mode of occurrence near Yenangyoung the youngest strata of the Irrawaddi division being chiefly exposed along the river bank south of Nyounghla and north of Yenangyoung.

The late Dr. Oldham[1] had already observed that the fossil bones are chiefly found in the ferruginous conglomerates and "breccia or conglomerate" which he has found at Minlindoung[2] and which is considered by me as the bottom-bed of the Irrawaddi division, and distinguished as a special bone-bed, of which more will be said later on. Besides this bed, I found fossil bones at several higher horizons, and I think that I am able to recognize certain well marked horizons characterised by their vertebrate fauna; this sub-division will be discussed presently.

As regards the fauna, which has left its remains deposited in the Irrawaddi beds, the following species and genera have been noticed by various authors. The first to determine the collection made by Mr. Crawford was Dr. Buckland, who recognised the following species:—

Mastodon latidens, Clift.
„ *elephantoides*, Clift.
Hippopotamus sp.
Rhinoceros sp.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp. *aff. vulgaris.*
Leptorhynchus sp. (*Garialis* sp.)
Trionyx sp.
Emys sp.

The specimens collected by Dr. Oldham, of which he has given a rough list at the end of his paper, have subsequently been more accurately determined, and I suppose that the list of fossils from Ava which Mr. Theobald gives[3] refers to them. The following species and genera are enumerated:—

Mastodon latidens, Clift.
Elephas cliftii, Cautl. and Falc.
Mastodon elephantoides, Clift.

[1] Mission to Ava, page 315.
[2] Dr. Oldham spells the word Menleng.
[3] Op. jam. cit., p. 67.

Rhinoceros sp.
Equus sp.
Hippopotamus (*Hexaprotodon*) *irravadicus*, Caut. and Falc.
Merycopotamus dissimilis Caut. and Falc.
Sus sp.
Tapirus sp.
Bos sp.
Cervus sp.
Antelope sp.
Crocodilis sp.
Leptorhynchus sp.
Emys sp.
Trionyx sp.
Colossochelys sp.

Most of these have been subsequently examined and described by Mr. Lydekker in the Palæontologia Indica and a few more species added to the above list, *viz.*, *Ursus sp.*, *Mastodon sivalensis*, *Rhinoceros sp.*, *Vishnutherium irravadicum*, *Bos sp.* The following species have been collected by me in the neighbourhood of Yenangyoung:—

1. *Mastodon latidens*, Clift.
2. *Stegodon cliftii* Caut. and Falc.
3. *Acerotherium perimense*, Lyd.
4. *Rhinoceros sivalensis*, Lyd.
5. *Hippopotamus irravadicus*, Caut. and Falc.
6. *Sus titan*, Lyd.
7. *Bubalus* sp.
8. *Boselaphus* sp.
9. *Hippotherium antelopinum.*
10. *Cervus* sp.
11. *Lutra* (?) sp.
12. *Crocodilis cf. biporcatus* (?).
13. *Gavialis sp. cf. gangeticus.*
14. *Emyda palæindica.*
15. *Trionyx* sp.
16. *Colossochelys atlas.*
17. *Testudo* sp.
18. *Emys* sp.
19. *Carcharias* sp.

Besides the species above mentioned, there are still some teeth representing three or four more species, which are, however, too ill-preserved to be determined.

Now, if we compare these lists of fossils collected at three widely separated periods, their great similarity is rather striking. In fact, although I had the best opportunity of all, my collection only adds a few more species to those already known through Dr. Buckland and Mr. Lydekker; but even these do not in the least alter the character of the fauna. If we omit the rather doubtful *Equus* sp. and assume that Mr. Oldham's *Antelope* sp. is identical with *Boselaphus* sp., the fauna consists of 26 species altogether. The character of this fauna is decidedly expressed by its composition, it being almost exclusively composed of animals which led either an entirely aquatic life or dwelt in swampy marshes bordered by shady forests, and required besides large quantities of vegetable food and an abundance of water for their welfare. Out of the 26 species above mentioned, seven are of entirely aquatic habits, *viz.*—

Crocodilis cf. biporcatus (?).
Gavialis, sp. cf. gangeticus.
Emyda palæindica.
Trionyx sp.
Colossochelys atlas.
Emys sp.
Carcharias sp.

To these we may add two which lead a semi-aquatic life, *viz.*:—

Hippopotamus irravadicus.
Lutra sp.

Out of the remaining species we may safely suppose that—

Rhinoceros [*Acerotherium*] *perimense.*
Rhinoceros sivalensis.
Rhinoceros sp.
Bubalus sp.
Sus titan.
Tapyrus sp.
Vishnutherium irravadicum.

and most probably also—

Merycopotamus dissimilis.
Hippotherium antelopinum.

chiefly dwelt in marshy swamps, while the remainder, *viz.*:—

Mastodon latidens.
Mastodon sivalensis.
Stegodon cliftii.
Boselaphus sp.
Cervus sp.
Bos sp.
Ursus sp.
Testudo sp.

most probably lived in the shady forests bordering the marshes.

The only region, in which were all the conditions for the existence of a fauna constituted as the above, would be the low islands and estuaries of the delta of a large stream. The numerous brooks and creeks afforded ample room and nourishment for the members of the reptilian tribe as well as for the sharks, while the low islands, covered with a luxurious vegetation, were the places where the *Ungulata* and *Proboscidea* led a comfortable life.

If we now examine the homotaxial relations of this fauna, it is at once obvious that it bears the strongest resemblance to the Siwalik fauna of India. Out of 26 species, at least 11 are recognized with certainty as being identical with Siwalik forms; these are:—

1. *Mastodon latidens.*
2. *Mastodon sivalensis.*
3. *Stegodon cliftii.*
4. *Rhinoceros* (*Acerotherium*) *perimense.*
5. *Rhinoceros sivalensis.*
6. *Merycopotamus dissimilis.*

7. *Sus titan.*
8. *Hippotherium antelopinum.*
9. *Gavialis sp. cf. gangeticus.*
10. *Emyda palaindica.*
11. *Colossochelys atlas.*

That is to say, all such forms as have been specifically determined, except those of course which are indigenous to Burma. Out of the remaining 15 species, two, *viz.*—

1. *Hippopotamus irravadicus.*
2. *Vishnutherium irravadicum.*

are indigenous to Burma, while the remaining 13 species have for the present been only generally determined.

The proportion of species identified with Siwalik forms is therefore, if we disregard the two indigenous species, about 50 per cent. of the total or much larger than Mr. Oldham supposed it to be.[1] In fact, I have not the slightest doubt that the proportion will be still greater once the fauna has been carefully studied, there being certainly among the 13 species hitherto only generally determined some which will be found identical with Siwalik forms.

On the other hand it cannot be denied that as regards the general character of the fauna of the Irrawaddi division, it exhibits some features decidedly different from the Siwalik fauna. The *Ungulata*, although being in the majority, are represented by a much smaller number than in the Siwalik fauna, but the most striking feature is the remarkable scarcity of *Carnivora* of which only two species have so far been discovered in the Irrawaddi division, which contrasts strongly with the large number of species in the Siwaliks. I am, however, not prepared to state that these differences are absolute, my opinion is rather that once the Irrawaddi division is more explored, and we know its fauna to a larger extent, the discrepancy between the total number of species on one side, and the remarkable difference of the development of the *Carnivora* in both regions will disappear, or at least become smaller.

For the present we must content ourselves with having pointed out that notwithstanding its smaller number of species the fauna of the Irrawaddi division must be considered as correlative to that of the Upper Siwaliks.[2]

Luckily in Burma we are in a much better position for ascertaining the age of the Irrawaddi division than were the Indian geologists, when fixing the age of the Siwaliks; as previously pointed out, the Irrawaddi division rests conformably on beds of miocene age. The natural conclusion is therefore that the Irrawaddi division represents the Pliocene of Europe, a supposition which is fully in accordance with the views lately promulgated by Mr. Oldham in the second edition of the Manual of the Geology of India, according to which "it is impossible to deny that the balance of evidence is in favour of a Pliocene age." In fact we might rather say that the evidence of the fauna of the Irrawaddi division is a further strong proof of the Pliocene age of the Siwaliks, for it would be impossible to assume that the Irrawaddi division was of Upper Miocene and not of Pliocene age. Such an assumption would simply mean a perversion of all facts and a negation of the natural divisions of the Tertiary rocks in Burma.

[1] Manual of the Geology of India, 2nd edition, page 341.

[2] Mr. Lydekker, when describing the fauna of the Siwaliks, never seems to have doubted this, for the specimens collected in Burma are included among his list of the Siwalik species.

Besides its fauna the Irrawaddi division is distinguished by an abundance of fossilized wood. In fact the fossilized wood has attracted the attention of travellers in Burma more than anything else with the exception perhaps of the occurrence of rubies. There is hardly a book dealing with Burma in which reference is not made to the fossil wood, and the quaintest theories have been set forth to explain its presence in such abundance. It is, however, strange to say that although quantities of it must have been brought to England since the end of the last century no scientific examination of it has hitherto been made.

The fossil wood is distributed throughout the whole of the Irrawaddi division, but I am unable to say whether there is any rule as regards its vertical distribution. Frequently enormous logs may be seen imbedded in the strata. I noticed a specimen of about 60 feet in length, east of Yenangyoung, broken into several pieces by its mere weight, but still partly imbedded in the soft sandstone. Pieces of smaller size are of course extremely common, and cart loads might be picked up in a few hours.

There are two modes of petrification, the one in which the wood fibre has been replaced by silica, the other in which it has been replaced by hydroxide of iron. The former is the common one; the latter has been only observed in a few cases of drift-wood imbedded in the ferruginous conglomerates.

The question as to how this wood became fossilized has of course occupied the attention of more than one observer, but it cannot be said that a satisfactory explanation has hitherto been given.

Mr. Theobald having observed that the fossil wood when found *in situ* never exhibits any signs of being rolled or otherwise worn away, nor gives any other indications of transport, therefore assumes that the wood could not have been in a petrified state prior to being embedded in its present position. He therefore supposes that petrification took only place after the trees had found their present resting place, an assumption which he explains by the following quaint theory. He supposes that the trunks of trees floated about till water-logged in shallow lakes, in which, on sinking, they became mineralised through the agency of springs holding silica in solution.

The logical outcome of this theory is, that wherever a single specimen of a silicified log is found *in situ,* we are bound to suppose that just underneath that very log, a spring rose, in order to petrify it, and, having done its work, disappeared without leaving behind it any other traces of its activity. The absurdity of such a theory is too evident, and no more need be said about it, but in discarding one theory one ought to be able to replace it by a more satisfactory one. I must, however, confess that in matters of this kind, which are chiefly of a chemical nature, I am unable to give a satisfactory solution. I was therefore extremely glad to find that Dr. Irving has propounded a theory regarding the origin of the silicified wood in the Pliocene of the Libyan desert[1] which might be equally well applied to the silicified wood of Burma. I cannot therefore do better than give Dr. Irving's own words, which are as follows:—

"Remarking on the silicification of wood, he wished again to emphasize the difference in the action of carbonic acid in petrological changes, according as it

[1] Quart. Journ. of the Geol. Soc., 1894, volume L., page 547.

existed as a free acid or in combination with a base, as in sodium carbonate. The extent of the "natron" deposits pointed to the supply of alkaline waters over large areas in former times, holding the mineral in solution. The reaction of such waters upon the potash felspar of the sands furnished, by the disintegration of the crystalline rocks, would not lead to the deposition of free silica (as in the ordinary process of kaolinization), because, while the potassium was taken up as a carbonate and carried away, the silica was also removed in solution, through combination with the sodium, to form sodium silicate. This last-named salt in solution would be readily decomposed by the organic acids and the carbonic acid furnished by decaying vegetable tissue, the silica being then deposited as a colloid *in situ*, and thus retaining the structural forms of the original tissue."

I may at once state that there is ample proof that the strata of the Irrawaddi division still contain the salts which were required for the above process.

This may here also be a fitting opportunity to correct an error, which though insignificant enough has been the source of the erroneous idea regarding the origin of the Irrawaddi division put forth in the 2nd edition of the Manual of the Geology of India. Mr. Theobald's statement that the silicified wood is never bored by xylophagous mollusca, has been used as a strong argument against the estuarine origin of the "Fossil wood group." The statement that the silicified wood is never bored by xylophagous mollusca is absolutely erroneous, as I have repeatedly found large pieces which have been riddled by the borings of these mollusca. Such pieces are rather rare, but still they exist, and with their existence the whole argument based on their absence falls through, which is another proof of the fallacy of negative proofs.

To conclude the palæontological features of the Irrawaddi division, I may mention here the curious flint flakes which have been found by me in the ferruginous conglomerate at the base of the group and which I described in a separate paper.[1] I may mention here that in the meantime several experienced colleagues have expressed their opinion that these flakes are in reality of artificial origin. As this is not a fitting place for the discussion of this question I simply record the fact without going into details.

d. Subdivision of the Irrawaddi division.

It is quite clear that the same reasons which render a subdivision of the Pegu division, extremely difficult apply also to the Irrawaddi division, even perhaps in a greater degree. It seems an almost hopeless task to subdivide this series of sandstones, clays, etc., of which the lowest exactly resemble in appearance a bed at the top of the series. But even after succeeding in working out a subdivision of a special locality, it is extremely difficult, if not almost impossible, to correlate the subdivisions of two somewhat distant localities, without having the connecting links.

Mr. Theobald's subdivision of the Fossil wood group in Lower Burma, as well as my own for the country around Yenangyoung, cannot therefore have more than local value. It may perhaps be probable that my subdivision, based on palæontological evidence, will eventually prove to be applicable over a larger area, but for the present there is no further support in aid of this supposition.

Mr. Theobald divides the Fossil wood group in descending order as follows:[2]—

[1] Records of the Geolog. Survey of India, volume xx, page 101.
[2] Op. cit., page 62.

a. Fossil wood sands.—Sand, in parts gravelly and conglomeratic, characterised by the profusion of concretions of peroxide of iron, associated with it. Fossils: Trunks of silicified exogenous wood, and, locally, mammalian bones. In the subordinate beds of conglomerate, rolled fragments of wood as above, silicified (that is, mineralized subsequent to their entombment), mammalian and reptilian bones and teeth of cartilaginous fish (squalidæ).

b. Fine silty clay.—Fine silty clay with a few small pebbles, mixed with sand, in strings here and there; the whole very fine and homogeneous and devoid of fossils.

c. Mogoung sands.—A mixed assemblage of shales, sands and conglomerates, the last very subordinate, partaking much of the charactersof beds *a* and *b*; a little of the concretionary oxide of iron. Fossils: rolled wood silicified, mammalian and reptilian bones and cartilaginous fish teeth. Towards the base, the beds contain marine shells and pass into those of the next group.[1]

For the country around Yenangyoung I divide the Irrawaddi strata into the following subdivisions in descending order:—

1. Yellow, soft and friable sandstones, alternating with beds of brown clay. Fossil wood not very common, no fossil bones.

2. Zone of *Mastodon latidens* and *Hippopotamus irravadicus.* Lithological characters as above; fossil wood very common.

3. Zone of *Hippotherium antelopinum* and *Acerotherium perimense.* Ferruginous conglomerate.

These three zones are of very unequal thickness, and although the boundary between zones 3 and 2 is a very sharp and natural one in a palæontological as well as in a lithological sense, yet that between the two upper zones (2 and 1) is more or less artificial, the division being simply based on the apparent absence of fossil bones in the upper beds of the series following immediately above zone 3. As a more detailed description of the development of the Tertiary system near Yenangyoung will be given in the memoirs of the Geological Survey of India, Vol. XXVII, it is unnecessary here to dwell any longer on this subject.

d. Distribution.

The Irrawaddi division caps the older Tertiary beds nearly everywhere in Upper Burma within the boundaries of the basin of the Irrawaddi. Of course it varies considerably in different parts of Upper Burma, but it can always be easily recognised. In Lower Burma it seems to cover a much smaller area, being apparently much eroded, so that only isolated patches remain, while in Upper Burma it forms a continuous cover, stretching from the foot of the Arrakan Yoma as far as the foot of the Shan hills.

The following table shows the manner in which I have subdivided the

[1] *Viz.*, Pegu group.

Burma Tertiaries, with the names given to each subdivision; these are arranged in such a way that at a glance it may be seen what principles have guided me:—

Character of fauna.	Name of Series.		Character of Deposits.	Character of sediments.	Name of division.	
Terrestrial and Fluviatile.	Burma series.		Deltaic.	Yellow sandstones, olive-coloured clays, ferruginous conglomerate; no gypsum.	Irrawaddi division.	
Marine	ARRAKAN SERIES.	UPPER.	Littoral and Estuarine.	Yellow sandstone, olive coloured and bluish clay; gypsum.	Yenangyoung stage.	Pegu division.
				Grey sandstone, bluish clay.	Prome stage.	
		LOWER.	Littoral	Limestone, grey sandstone, bluish clay.	Nummulitic division.	
			Deep sea	Shales	Chin shales.	

In concluding this sketch of the Burma Tertiaries, the following table will convey my views as to the correlation of the Tertiary strata in Burma, India and Europe. It would, of course, be useless to attempt anything beyond a general comparison, and, I think, we must be satisfied if we recognize with some certainty the large sub-divisions of the European Tertiaries in distant Burma.

The Tertiaries of India, of which those of Burma form only the eastern continuation, exhibit, by their remarkable division into two large groups differing widely in the character of their respective faunas, such peculiarities that any correlation with the Tertiary rocks of Europe, except one based on the broadest lines, is almost impossible, a fact which has already been noted by Dr. Blanford.

Europe.	Burma.				Western India.	Himalaya, North-West area.	Himalaya, Simla area.
Pliocene.	Burma Series.			Irawaddi division.	Manchhar group.	Upper Siwaliks.	Upper and middle Siwaliks.
Miocene	ARRAKAN SERIES.	UPPER.	Pegu division.	Yenangyoung stage.	Gaj group	Lower Siwaliks.	Nahan beds Lower Siwaliks.
				Prome stage.	Nari group	Murree beds	Kasauli group.
Eocene		LOWER.		Nummulitic division.	Kirthar group	Upper and Lower Nummulitic.	Dagshai and Subathu group.
				Chin shales	Ranikot group	?	?

Notes from the Geological Survey of India.

I. Rewah.—" Vindhyans."—Mr. Oldham and Mr. Datta have been at work in the Rewah State, north and south of the Sone river; their surveys have already resulted in most interesting and, in some degree, rather startling facts, some of which are briefly noticed in the Annual Report; but since the latter has been set up in type some new facts are reported by Mr. Oldham. He distinguishes the following rock groups in ascending order:

(*a*) A transition series, into which granitic rocks intrude, locally altering them into schists; Mr. Bose had separated the latter from the transitions as a separate system, but Mr. Oldham shows this to be unnecessary.

(*b*) The transitions are unconformably overlaid by a series of rocks, consisting of a basal sandstone and conglomerate, indistinguishable from similar beds at the base of the so-called lower Vindhyans, followed by a great but indeterminable thickness of red, and occasionally green, slaty rock.

(*c*) This series is again unconformably overlaid by the so-called lower Vindhyans; Mr. Oldham drops that name and returns to the older term of the Semri series first used by Mr. Medlicott for the rocks of the same age in Bundelkhund. He has obtained evidence that this series is distinct from the

(*d*) Kymore group or Vindhyans proper, which rest unconformably on the Semri series.

Gondwanas.—Mr. Oldham re-examined a small coal-field, which Mr. Smith had partly surveyed some years ago; the Barakar age of the rocks has now been established, as they contain Vertebraria, Glossopteris, Schizoneura, etc. Mr. Oldham met with two coal-seams, respectively of 6′ and 5′ 6″ thickness; the former is 1½ miles south-west by west of Ujeini, the latter 2 miles north of Amilia, both places near the eastern edge of sheet 476.

II. Madras.—Mr. Middlemiss was engaged during January in examining the magnesite area of Kanjamallai, regarding which he reports:

(*a*) The ultra-basic rocks of the north-west end of Kanjamallai and the derivative magnesite (first discovered by Mr. Holland) were found to be much the same as those of the Chalk Hills. Their extent is, however, insignificant. Olivine-bearing ultra-basic rocks were found to run in a broken band nearly east to west from near Ellampaddi to the point at which the ridge becomes steeper, towards the high western end of Kanjamallai ridge. Pure olivine-rocks, such as compose much of the fundamental rocks of the Chalk Hills, are wanting here. Chromite was found at the eastern end of the band with the magnesite, running as a vein, 4—5 inches wide, through the serpentinized olivine-bearing rock. The amount of this mineral exposed is small. Excavations alone could decide its worth. The magnesite is too unimportant for economical purposes.

(*b*) South of Kanjamallai, a ridge near Ariyanur is composed of altered ultra-basic olivine-rock very closely resembling the dunite of the Chalk Hills. The same rock "massif" becomes talcose, with beds of rather impure potstone, which is locally excavated for making into vessels. A few unimportant magnesite veins occur in this ridge. Incidentally sections were carried round and across the Kanjamallai ridge, and the valuable magnetite bands were located and mapped on the 1-inch maps as closely as possible. The conclusion arrived at was that only the lowest band need be considered from an economical standpoint, because it seems to be the only one which contains the richer and compacter form of the ore.

(*c*) Between Macdonald's Choultry and Konganapuram, several veins of coarse graphic granite with mica were traced; they seem to be connected with the Idapaddi veins and mica quarries. The great granitic area of granite veins (in a biotite gneiss), of which the Sankaridrug hill forms one summit was mapped.

Mr. Middlemiss afterwards examined the rocks of Valaiyapatti and reports:

(*a*) *Magnesite and ultra-basic rocks.*—The magnesite occurs in very small quantities. The rocks associated with it resemble entirely those at the north-west end of Kanjamallai, as far as their appearance in the field permits an opinion. The absence here as at the latter place of pure olivine rock or dunite is noteworthy. Forming a long low ridge running east and west from Valaiyapatti there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapatti. The graphic granite was probably intruded last.

(*b*) *Charnockite south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road occurs a great exposure of Charnockite. From its position, strike and general appearance it is a continuation of the Shevaroy hills massif.

(*c*) *Chalk hills.*—As a whole, the aspect of each magnesite area in the Chalk hills near Salem is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity.

At the centre of each area occurs the chromite in veins among the dunite and serpentine. Surrounding this is a paler dunite zone (almost pure olivine, partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area, come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

III. Sind. (*a*) *Salt.*—Mr. LaTouche, while superintending the trial-boring for oil at Sukkur, had occasion to examine a very interesting occurrence of rock-salt in nummulitic limestone. The spot where this mineral is found is about half a mile south-east of the village of Aror, which lies at about 4 miles east of Rohri on the left bank of the Indus. Here the low ridge of nummulitic limestone, which extends from Sukkur and Rohri for about 50 miles southward, is intersected by a broad valley, through which the Indus is said to have flowed in former times. On the south side of this valley, in the precipitous scarp overlooking the alluvial plain of the Indus, a band of nummulitic limestone is found about 20 feet from the base of the scarp, and portions of this band contain chloride of sodium in the form of nests and strings, whilst the whole band possesses a slightly saline taste.

(*b*) *Oil.*—Near the village of Kundra, about 8 miles south of Rohri, the natives of that part of Sind knew of a spot where a strong smell of earth-oil could be perceived, and where they used to drive their cattle during the hot weather, as flies are said to avoid the place, which is in the midst of a sandy plain, the present alluvium of the Indus. Latterly Mr. LaTouche had a well dug to ascertain the cause of the exhalations; at a depth of about 16 feet from the surface, the volume of gas issuing from the soil became so large that the men employed could no longer work in the hole without danger of suffocation. Indeed, in two instances, they were so overcome for the time being that they had to be hauled up with ropes. It was therefore necessary to continue sinking the well by means of an improvised dredger worked from above, and after a good deal of labour water was reached at a depth of 20 feet from the surface. On continuing the sinking for two feet or so below the level of the water, films of oil began to appear on the water, and on dredging up some of the sand from the bottom these films could be seen oozing from it upon the water. The quantity is of course exceedingly small, but it is enough to show that there is probably an escape of oil from the rocks below the alluvium, sufficiently large to have impregnated the latter, which is possibly some hundreds of feet in thickness at that spot. The indications are sufficiently promising to justify the sinking of a boring here.

The gas which escapes from the well is apparently composed principally of carbonic acid, for a light is immediately extinguished by it. But from its smell it is probably mixed with some gaseous hydrocarbon. It is probably caused by the oxidation of hydrocarbons during their slow passage through the alluvium.

There is no outcrop of solid rock anywhere in the neighbourhood of the well, the nearest being the scarp of nummulitic limestone, which forms a low ridge running south from Rohri and about 6 miles east of the well. The intervening ground is covered by the alluvium of the Indus, and at the bottom of the well, fine dark grey alluvial sand was found.

IV. Gondwanas in Argentina.—Dr. Fritz Kurtz, Professor of Botany at the University of Cordoba Rep. Argentina, writes to Dr. F. Noetling that in 1887 he received some fossil plants from Bajo de Velis in the Sierra de San Luis, amongst which he determined a *Neuropteridium* sp., he considered the species as new and described it as *N. argentinum*, Kurtz. However, after having received Vol. III of Feistmantel's Gondwana flora, he recognized at once that his new species was identical with *N. validum*, Feistm, from the Kaharbari beds.

Since that discovery he received some more fossil plants from Cachente, Uspallata (east slope of the Cordillera) and others from the abovenamed locality: among the latter he recognized:

Gangamopteris cyclopteroides, Feistm.
Neuropteridium validum, Feistm.
Noeggerathiopsis hislopi, Feistm.
Equisetites sp. nov.
Sphenozamites sp. nov.
Walchia (?) sp.

To this discovery, which is of the utmost importance for the homotaxy of the Gondwanas, I may add that it forms an additional evidence for the general similarity of geological structure between the southern part of South America and South Africa; we have in both continents marine devonian strata which have yielded practically the same fauna.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

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RECORDS

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On the Jadeite *and other rocks, from* Tammaw *in Upper Burma: by* PROFESSOR MAX BAUER, *Marburg University: (translated by* DR. F. NOETLING *and* H. H. HAYDEN).

In the following pages I propose to describe the rocks collected by Dr. Noetling at the jade mines near Tammaw in Upper Burma, and which are now in the collection of the Geological Survey of India. These specimens including the jadeite and the serpentine (the most important) bear all the characteristics of true rocks.

Jadeite.

Jadeite.—The jadeite forms a fine-grained mass, chiefly white, and bearing at first sight a certain resemblance to marble. The size of the grains is not uniform; they are at times so small as to be indistinguishable by the naked eye, while at times they are somewhat larger, in which case they are characterised by an elongated form and distinct cleavage. On account of the smallness of the grains no single individual could be separated, and further information could be obtained only by means of the microscope. I will, however, first describe the general appearance of the jadeite.

General characters.

The colour of all specimens under my observation is a clear snow-white on fresh fracture; this monotonous white is, however, relieved by beautiful emerald-green spots, which represent the really valuable part of the stone. They are of variable size, being sometimes as large as a lentil or a pea, sometimes attaining a diameter or several centimetres. The colour is in many cases very intense, but in others again quite pale, at times forming a faint film-like covering over larger or smaller portions of the surface. As it approaches the white mass of the rock, the colour changes abruptly, without, however, there being any well-defined boundary between the two. The green colour is due to the presence of a small quantity of chromium, for powder of an intensely green colour gives an unquestionable Cr. reaction before the blowpipe: this, however, is less distinct when paler powder is used, and is entirely absent in the white portions of the rock. In the inner portions, when fresh, the lustre is vitreous, but towards the surface becomes somewhat duller. The fracture is uneven and splintery, while the hardness exceeds that of felspar, but is not so high as that of quartz. The tenacity is not very high; at some places splinters can be easily removed. This character varies, however, in different specimens, and at times even in the same specimen. This I believe to be due to disintegration, and also in part to cataclysmic structure, which, as we shall presently see, is a characteristic feature of the jadeite from Tammaw.

Special care was exercised in the determination of the specific gravity owing to the fact that in samples of jadeite from Bhamo, which might perhaps be considered identical with specimens from Tammaw, it was found to be very low. The average specific gravity of the Tammaw jadeite is about 3·3, while Issel gives that of two specimens of green jadeite from Bhamo, as 3·10, which corresponds with the values obtained by Damour. Mallet states that the s.g. of the Tammaw jadeite is 3·24. Six specimens of different degrees of coarseness served for my observations. In all of them the s.g. is high, and averages about 3·3, being sometimes higher, sometimes lower. By means of the hydrostatic balance and the pyknometer the following figures were obtained:—3·338, 3·332, 3·330, 3·329, 3·327, 3·325. No connection could be traced between the specific gravity and the texture of the rock. This variation of the s.g. is probably due to small differences in the chemical composition. It is, however, difficult to explain the wide divergence of the results obtained by Issel, Damour and others, and only by the examination of the s.g., chemical composition and microscopic characters of further material can we hope to solve this difficulty. All this, however, should of course be done for one and the same piece.

Specific gravity.

Dr. Busz has made an analysis of one of the coarse-grained pieces (s.g.=3·332), using as fresh and pure a portion of the rock as could be obtained. The results of his analysis are given under I. He specially notes the absence of chromium and oxides of iron.

Chemical composition.

	I.	II.	III.	IV.	V.
SiO_2	58·46	59·27	57·63	58·99	59·45
Al_2O_3	25·75	25·33	24·10	24·77	24·32
Fe_2O_3	...	...	...	·32	·36
CaO	·63	·62	·62	·14	·22
MgO	·34	·48	·48	Traces.	
FeO	...	·71	·71	...	...
Na_2O	13·93	13·82	13·82	14·51	14·42
Loss	1·00	...	...	1·14	1·15
	100·11	100·23	97·36	99·87	99·92

The figures obtained by my analysis (I) very nearly agree with those obtained by Damour from a jadeite from Asia (II). If we adopt the views expressed by E. Cohen (Neues Jahrb. für Min., etc., 1884, Vol. I, p. 47), the jadeite under examination as well as that analysed by Damour would have the following composition:—90·1 per cent. of $Na_2O, Al_2O_3, 4 SiO_2$, 4·59 per cent. of $MgO, Al_2O_3, 4 SiO_2$, 1·28 per cent. of CaO, SiO_2. On the other hand the silicate FeO, SiO_2, which has been found in most other jadeites, is entirely absent, while in that from Asia 1·3 per cent. is present. Column III represents the average of I and II, while IV and V give the figures obtained by Oliver C. Farringdon[1] from an analysis of jadeite from Mogaung.

The microscopic examination shows that the ground-mass is composed of a confused aggregate of irregular prisms, varying in size; their length and breadth being in some cases the same, and nearly equal to 1 mm., but as a rule the prisms are elongated, their length considerably exceeding their breadth. In no case, however, did I observe a breadth

Microscopic characters.

[1] Proceedings of the U. S Nat. Museum, Washington, 1894, Vol. XVII, No. 981, pp. 29--31.

of less than 0·1 mm. The ground-mass of the jadeite is perfectly pure, and without a trace of any accessory mineral. The prisms are perfectly colourless, except at the boundary between two individuals or along small cracks, where a slight discolouration may be seen, probably due to subsequent infiltration. The green spots always retain their colour even in slices: it is, however, very pale, even in cases in which it was originally intense. In very pale sections no pleochroism is noticeable, but thicker slices are slightly dichroic, the colours ranging from a bluish to a yellowish green. The prisms are at times colourless in places. In the centre of the green spots they are coloured, but as they approach the surrounding white ground mass, they begin to lose their colour, and become partly green and partly white. Hence we see that the green patches in the white ground cannot be due to an aggregation of green mineral grains at certain spots, but we must imagine local inpregnations to have taken place by means of a colouring matter containing chromium in solution. This permeates each spot with such uniformity that it does not appear to have any well-defined form even under the highest powers of the microscope. The green prisms are exactly similar in every respect to the white ones, with the sole exception of their different colour. No pitting of the surface can be noticed, the crystals appearing perfectly smooth: hence their refractive index is not high. Very minute liquid enclosures are locally numerous, occurring at some spots in aggregates of several individuals: more often, however, they are entirely absent. The characteristic cleavage of augite is very frequently extremely well-marked. In cross-sections the two cleavages intersect almost at right angles. The angle, however, depends of course on the direction in which the section has been cut. In none of my observations could I discover any difference in the two prismatic cleavages, which appear to be everywhere equally perfect. Hence, the cleavage of jadeite certainly does not justify us in including it among the triclinic minerals. In addition to prismatic, pinacoidal cleavage also occurs, and still more frequently, a cleavage transverse to the prismatic zone similar to that of diopside and other pyroxenes. The angle between the cleavage in this direction and that parallel to the prism faces is about 90°. I obtained values up to 96°, but this angle depends of course on the direction in which the slice has been cut. These cleavages frequently subdivide the prisms into single segments, having a strong resemblance to cross-sections of the prisms. They differ, however, from the latter in being less regular.

In polarised light, the prisms show very vivid interference colours. On sections with oblique extinction, the angle of extinction is very high, rising to 40°. Numerous longitudinal sections, however, have straight extinction, one direction being parallel to the cleavage and the other normal to it. In convergent polarised light the perfectly transparent crystals give very fine and clear interference figures, while owing to the thinness of the slide the narrow rings, as well as the vivid polarisation colours in parallel light, indicate a strong double refraction. According to the direction in which the section has been cut, these figures show the well-known differences in shape. On longitudinal sections, however, with straight extinction, one or two axes always undergo dispersion, with a wide axial angle, and the plane of the optic axis is parallel to the cleavage and perpendicular to the direction in which the section has been cut. If we include jadeite in the monoclinic system, then these sections are parallel to the axis of symmetry and the axial plane becomes the plane of symmetry. The above optical property is intimately connected with the crystalline form, and corresponds to that of all other monoclinic pyroxenes, which, without exception, show inclined dispersion. This, however, cannot be observed in the case of jadeite, owing to its wide axial angle. If, on the other hand, we place jadeite in the triclinic system, these optical properties will be anomalous. It seems therefore impossible to suppose that the mineral belongs to that system. It is true that in cross-sections, the directions of extinction are frequently not symmetrical to both cleavages. This symmetry, however, is found in the monoclinic system only when the direction in which the slice has been cut is parallel to the axis of symmetry. Otherwise, the direction of extinction forms different angles with the two systems of cleavage, and the difference of the angles depends on the more or less symmetrical position of the cleavage prism with regard to the plane in which the section has been cut. The optical symmetry is therefore no proof of the triclinic character of the mineral; and in our special case has absolutely no weight, inasmuch as cross sections also occur showing optical symmetry. The above refers chiefly to the properties of a single individual of jadeite. These, however, are frequently intergrown, and at times occur as a number of long prisms, forming a divergently radiating group with interpenetration, and producing a perfectly uniform groundmass. The longitudinal axis of the prisms do not point in any one direction more than in another, hence the groundmass consists of an aggregate of completely directionless individuals. In none of the specimens, however, is the original structure entirely unchanged. Frequently it is locally very distinct, but equally frequently it is more or less disturbed, in which case the prisms are no longer straight, but become more or less curved, and not infrequently distorted and broken: the fragments are then pushed out of place and a differently oriented substance squeezed in. The distorted prisms frequently exhibit at their ends a sort of fringing, which like the distortion is the result of mechanical action. The result of this action, however, is not merely bending and distortion, or fracture and fringing at the ends, but it even extends to the total smashing of the entire groundmass, which then no longer consists of elongated prisms, but becomes an "aggregate-polarising" agglomerate of small grains, which are the remains of the crushed prisms. Some of the prisms still remain in the fine-grained aggregate, but they clearly exhibit bending, distortion or some form of deformation. Sometimes it is possible to trace a transition from the fine grains to the complete prisms. In fact, this is one of the finest instances of cataclysmic structure, which can only be explained by means of violent compression of the already formed rock. The structure is of course better developed in some specimens than in others; but wherever it is well-marked, two other phenomena may be observed in those jadeite prisms which have been preserved: these are evidently due to the same causes as the cataclysmic structure. One of these phenomena is an undulating extinction which is apparently attributable to a slight deformation of the jadeite prisms. The other is polysynthetic twinning, so similar to that of plagioclase, that at first glance the twinned jadeite crystals might easily be mistaken for that mineral. The jadeite twins, however, gradually pass into single prisms, and the general properties of the twinned crystals are so exactly similar to those of the single individuals that no doubt of their identity can be entertained. The twin lamellæ are not very broad; in fact, as a rule, they are narrow; they are always numerous, more particularly in the latter case. Twinned prisms are frequently bent throughout and fringed at the ends. It appears that the twins are most numerous in the portions that have suffered the greatest crushing, and are absent where the effects of pressure are not well marked. We must conclude, therefore, that under favourable conditions crushing and pressure would produce in the jadeite a re-arrangement of the molecules into twins, similar to that observed in calcite. This, however, must have happened only in rare cases, for it had not hitherto been observed. The twinning, plane, which in this case must be looked upon as a fault-plane, is distinctly seen to be a transverse plane, corresponding to that otherwise observed as a twinning-plane in pyroxene.

2. *Serpentine.*—The groundmass of the serpentine is dense, appearing completely homogeneous, with a very dark, somewhat brownish-green colour, which spreads evenly over the whole surface. Fracture uneven and splintery. Hardness considerable, exceeding that of pure serpentine: apatite is distinctly scratched in some instances. Under the microscope the cause of this anomaly is at once evident; for the specimen is seen to be an altered olivine-rock, the alteration of which into serpentine is not quite complete, but the process of serpentinization is proceeding in the usual manner along cracks and fissures. In microscopic sections, the olivine is perfectly colourless and transparent: in thick slices, however, it shows a greenish-yellow tinge. It forms an aggregate of rather coarse grains, which in several instances have a diameter of more than 1 cm. They are always irregularly circular, no indication of crystal faces being traceable. Between the larger grains, which throughout the slide extinguish simultaneously, occur aggregates of very minute, confused and variously oriented grains, which appear to be derived from larger olivine grains. This phenomenon seems to be analogous to the cataclysmic structure of the jadeite, a view which is supported by the fact that the serpentine possesses other properties which are undoubtedly due to mechanical pressure. The olivine individuals and also the aggregates formed by the small grains are intersected in the usual manner by strings of serpentine of a greenish-yellow colour, which usually show a distinct and very fine fibrous structure, running in most cases parallel to the walls of the small fissures: in a few cases, however, they are perpendicular to the walls. The rock is therefore a fibrous serpentine, very similar to chrysotile, and closely resembles it in the vividness of its polarisation colours. In microscopic slices these rise to the blue of the 2nd order, but by a combination of several fibres lying one upon the other, fall at times to an iron-grey of the 1st order. In all fibres, the direction of extinction is parallel to the fibres, corresponding to the axis of least elasticity as in the case of chrysotile. The strings intersect each other very irregularly as a rule, but occasionally cross in straight lines at right angles to one another, in which case, when the olivine appears dark in polarised light, a regular mosaic-like structure is produced. With the exception of numerous small black grains, with metallic lustre, no other minerals but olivine and serpentine can be seen. These black grains having a diameter of 1 mm., are magnetic, and hence are probably magnetite. B. b. they give no titanium reaction. Some of the grains are not magnetic, and in the borax bead give a marked Cr. reaction: they must therefore be chromite or picotite, most probably the former, as they did not appear to be particularly hard. These grains are unquestionably the

Serpentine. General appearance.

Microscopic characters.

Olivine.

Serpentine.

Magnetite and other accessory constituents.

source of the Cr. which permeates portions of the jadeite, producing the green patches. In the specimens under observation, however, no mineral can be identified as chromite or picotite; if, however, a larger number of specimens were examined, I have no doubt that sections of both minerals would be found. Under the microscope, the grains of magnetite exhibit very regular octahedral outlines; they are sometimes single, but not infrequently form parallel aggregates of small individuals, which, however, are not true skeleton crystals. The whole of the magnetite is always found among the serpentine fibres, and not a trace can be discovered in the fresh unaltered olivine: it is therefore unquestionably a secondary product of the alteration of the olivine into serpentine. A specimen of the serpentine rock, which had been freed as much as possible from magnetite, gave a s. g. of 2·838. If we take the s. g. of pure serpentine as being that of the pikrolite from Amelose, *viz.*, 2·551, and further if we take the s. g. of pure unaltered olivine as being that of chrysolite from the East, *viz.*, 3·331, we deduce from the s. g. of the serpentine from Tammaw (2·838), the fact that it contains 43·19 per cent. by weight of olivine and 56·81 per cent. of serpentine. The percentage by volume being—

Specific gravity.

Composition.

Olivine	36·79 per cent.
Serpentine	63·21 „ „

These figures are of course not absolutely correct, but give a very fair idea of the composition of the groundmass, and certainly prove that not more than one half of the original olivine has been altered into serpentine. The newer portions of pure serpentine, usually observed in connection with this form of alteration, are not absent in the present case. Strings of pikrolite, in particular, may be seen running through the rock. These veins are of lighter colour than the chief mass of the rock, and are, as a rule, very narrow. Some, however, attain a thickness of nearly 2 cm. Some specimens, the outer surface of which is composed of pikrolite, exhibit the characteristic course, straight, striated appearance, producing the effect of a slickenside; and one of these specimens gives unmistakable evidence of the tremendous crushing and pressure which I have already mentioned. Numerous fissures distorted and bent and sometimes very complicated pass right across the striations, occasionally dying out and being replaced by new ones. They are partly filled with finely fibrous serpentine, resembling chrysotile, the fibres of which are usually normal but sometimes oblique to the walls of the fissure. Occasionally they contain pikrolite, of varying microstructure, of which I shall speak presently. The striæ on the pikrolite are displaced by these fissures, producing step-like markings on the striated surface. Sometimes, in consequence of this displacement, single parts are forcibly bent, and the pikrolite more or less squeezed into the olivine and serpentine. Evidence of the same crushing may also be seen in other specimens of the serpentine. In one case the result is a number of thin lamellæ, while the whole mass is squeezed into an irregularly rounded lenticular form, the rock having a soapy feel. On fresh fracture, the pikrolite has faint fatty lustre, but on the natural surface this lustre is much more marked. The colour is light green, with a distinct greyish or yellowish tinge. Only very rarely is the colour uniform, darker patches usually occurring here and there. The surface of the specimens, and at times even the walls of the inner fissures, are covered with a thin layer of a

Pikrolite.

white substance of lustre varying from mother-of-pearl to fatty. Like the serpentine fibres which intersect the olivine, the pikrolite contains much magnetite in the form of irregular grains, some of which are as large as a pea or even a hazel-nut. I have found no non-magnetic metallic grains, nor could I obtain any Cr. reaction. To the naked eye the pikrolite is perfectly opaque.

In places, the newly formed mineral is coarsely fibrous, the fibres being bent and curved, and the mass having the appearance of metaxite. True chrysotile, recognisable by its peculiar silky appearance and metallic lustre, does not seem to occur in large quantities. The specimens under observation show indications of it, but not its typical development. Under the microscope, the pikrolite is light yellow, almost colourless, and not pleochroic. It can hardly be distinguished from the surrounding Canada balsam, and must therefore have the same refractive index. Brownish patches occur here and there in the colourless groundmass, these are due to infiltration of hydroxide of iron. Their structure is always radial to fibrous, but the fibres are not so fine as those of the pikrolite. Not infrequently, broader fibres occur, forming divergent clusters. Like the single rays and fibres these clusters cross one another confusedly at various angles. Larger grains of magnetite are fairly common, always quite fresh and intimately associated with the rays and fibres, at times completely surrounding them and producing the effect of fluidal structure. The polarisation colours are blues of the second order, and, more often, iron-greys of the first order.

The pikrolite which occurs in strings and fissures, differs from that just described. This variety is formed in the centre of small radiating fibrous clusters, which in polarized light very distinctly show the black cross: the more nearly they approach to the walls of the fissures, the smaller do these clusters become; and they decrease in size more and more, till at length they disappear, becoming so small that even under the highest power of the microscope (× 600) they cannot be individualised. In this case, the whole seemingly structureless mass exhibits in polarised light an iron-grey colour, in which may be seen here and there a black cross, due to some larger clusters embedded in the minute ones.

I have already mentioned a white mineral which covers the surface of the plates of pikrolite and fills up the fissures. To judge from its mother-of-pearl lustre and soapy feel one would be inclined to identify it as talc. Under the microscope, however, it is seen to be a confused mass of mineral fibres resembling pik rolite; but whether it is fibrous pikrolite or chrysotile can only be determined by chemical analysis, for which the material at my disposal is not sufficient. It is highly probable that, comparatively speaking, a large proportion of this mineral composes the intermediate layer between the serpentine and the jadeite. Unfortunately, however, I have no specimens of that layer.

Certain other substances accompany the serpentine in small quantities. Grown over the pikrolite are small blackish-brown grains, exactly resembling webskyite as first described by R. Brauns. This mineral was discovered in some serpentines derived from palæopikrite from Hessen, Amelose and Reichenstein in Silesia. In miscroscopic slides, these grains become of a light brown colour and transparent, being scarcely affected by polarised light. Unfortunately there is not sufficient material for a more exhaustive examination, but such characteristics as I have succeeded in observing, agree so well with webskyite that there can be no doubt as to their identity, and R. Brauns was therefore correct in assigning such a wide distribution to that mineral. In addition to the above mineral, there occur small rounded or string-like and very fine-grained portions of a mineral of yellowish colour, not affected by hydrochloric acid. This may possibly be a hornstone quartz, such as is frequently found in serpentine. Carbonates, which are not uncommon in serpentines, are entirely absent, for no trace of effervescence could be observed either with hot or cold HCl.

Albite-hornblende rock.
General appearance.

3. *Albite-hornblende rock.*—The only specimen under my observation is of about the size of the fist, and apparently formed part of a large boulder exhibiting both rolled surfaces and fresh fracture. The rolled surface is brown owing to impregnation by hydroxide of iron, the coloration extending for some distance within the rock, but gradually fading and eventually disappearing. At the first glance, one would be inclined to identify this rock as a saussuritic gabbro, owing to the appearance of the fractured surface. The fine white sugary groundmass contains grains of a brown mineral, which cleaves easily and has a metallic lustre on the cleavage faces. Examination proved, however, that these two component parts are neither saussurite nor diallage, and hence the rock is not a saussurite gabbro, but represents a new type. The beautiful, snow-white groundmass is almost indistinguishable from some saussurites, as, for example, from that of Hamberge near Frankinstein in Silesia. It has the hardness of felspar, and fuses with great difficulty before the blowpipe. The s.g. of two fragments were 2·599 and 2·576, which gave an average of 2·587.

Specific gravity.

Microscopic characters.
Albite.

Under the microscope, the groundmass is seen to be a homogeneous aggregate of very small irregularly rounded grains, varying in size from ·02mm to a fourth or fifth of that size. These grains are almost perfectly pure; enclosures being entirely absent, with the exception, perhaps, of a few small liquid enclosures with moveable bubbles. The grains are perfectly transparent and colourless, and between them occur foreign particles, which, however, are never included in them. The white grains show no cleavage faces, but are crossed in one direction by a series of fine cracks, indicating a perfect cleavage. In some cases numerous fine twin lamellæ of plagioclase occur: these, however, are not very common. The polarisation-colours are very vivid, and the surface of the grains is perfectly smooth and without any pitted appearance. Some grains give the interference figures of biaxial crystals, with a wide axial angle, which, however, cannot be measured. According to the analysis of Mr. Busz, the white groundmass is composed of—

Chemical composition.

	I	II
SiO_2	64·60	68·62
Al_2O_3	19·92	19·56
CaO	traces.	—
MgO	traces.	—
K_2O	1·02	—
Na_2O	14·01	11·82
	99·55	100·00

It is therefore unquestionable that this represents an aggregate of albite grains most of which are single individuals. This view is also borne out both by the chemical and physical properties of the mineral. The composition certainly appears to differ somewhat from that of pure albite given under No. II, but we must remember that the groundmass is not entirely composed of pure albite, but also contains the foreign particles, of which we shall presently speak. The groundmass is slightly affected by HCl., and although albite has been stated to remain unaffected by this acid, it is undoubtedly acted on to a certain extent.

Hornblende.

The brown mineral resembling diallage, scattered through the white groundmass, has been proved to be hornblende. It occurs in single crystals of various sizes, the largest being nearly 4 cm. by 2 cm. This, however, is less than the original size of the crystal which was on the surface of the specimen and has been considerably broken. As a rule, the crystals are smaller, but are always as large as a pea. They are not numerous, being scattered throughout the rock. Their outline is generally irregular, although at times rough crystal faces can be made out. The colour is that of brown hair, but sometimes grey, and the cleavage faces have a metallic lustre, resembling diallage or bronzite. Each crystal is bounded by a green margin, while the surrounding groundmass is also coloured green. In both cases, this coloration is due to numerous microscopic enclosures to which I shall presently refer. In all these hornblende crystals, one of the two very well marked cleavage faces is unusually large, and thus gives the crystal its resemblance to diallage or bronzite. The second cleavage is everywhere equally perfect, and these two meet at an angle of 124° $47'$, the characteristic angle of hornblende. This value was obtained by measuring three separate splinters, and in every case the results only differed by a few minutes. On one of those splinters a broad plane was observed truncating the obtuse prism edges; this plane corresponds to the orthopinacoid (100, $\infty \bar{P} \infty$) The hornblende showed no signs of fibrous structure.

Owing to the small amount of material at my disposal, I was unable to make an analysis. The green margin, however, as well as those parts of the albite groundmass which surround the hornblende crystals, gave with borax an unmistakable Cr. reaction; but no Cr. could be detected either in the brown or greyish portions of the hornblende or in the white albite. The micro-chemical examination of the hornblende proved the presence of silica, magnesia, lime, iron, and a little alumina but no alkalies. The average s.g. of the brown splinters was obtained in methylene iodide, and proved to be 3·10, being the average of two separate operations. These figures, as well as the cleavage and the other properties of the mineral, enable us to identify it with hornblende. In the Bunsen flame small splinters are slightly discoloured but do not melt. They melt easily, however, before the blowpipe, fusing to a grey non-magnetic glass. Iron must therefore be present in small quantities. Extinction is straight, parallel to the very distinct cleavage-fissures. Thicker slices exhibit very distinct pleochroism, which, however, entirely disappears in thin sections. The vibrations parallel to the axis of symmetry, and therefore perpendicular to the cleavage cracks, are light brownish-red, while those parallel to the cleavage are light yellow, and those perpendicular to both are light bottle-green. These colours differ but slightly in intensity, while the colour changes from red to green or yellow according to the direction in which the hornblende crystals have been cut. Occasionally, especially at the margin of the crystal, the colour becomes a deep bottle-green or even emerald green: this is most probably due to infiltration of a foreign substance containing Cr. These greenish patches gradually pass, without well-defined margins, into the differently coloured parts. Cross sections having the characteristic hornblende cleavages intersecting at 124°, extinguish diagonally, while the pleochroism varies from brownish-red to green. On longitudinal sections, the angle of extinction is as much as 19°.

Augite.

In the boundary zone between the hornblende crystals and the albite, a large number of needles of a green mineral occur. These are most numerous along the boundary, and decrease in number on each side of it, thus producing intensely green bands round the hornblende crystals. In the albite aggregate, these needles lie in all directions between the albite grains, but are never enclosed by them. In the hornblende, they not infrequently lie parallel to the cleavage, but more often they are disposed quite at random obliquely to the cleavage fissures. They are always straight, and their length, as a rule, is three or four times their breadth in the broader needles, while in the narrower ones the length is much greater. Their sides generally consist of sharp straight lines; sometimes, however, both edges are slightly curved, thus producing spindle-shaped sections. If the ends are not pointed, they are, as a rule, rough and irregularly indented, but never fringed nor bifurcating. The oblique extinction is important, and rises to as much as 36°. Not infrequently square cross sections may be seen, at times extinguishing parallel to the edges. Cleavage is probably present, but it is not well-defined. Transverse fractures obliquely inclined to the longitudinal axis are common. The characteristics above enumerated enable us to identify this mineral with augite. The colour of the larger prisms is an intense bottle-green to emerald-green, and thus produces the green zone already mentioned as occurring round the hornblende crystals. The narrower needles are of lighter colour, while the narrowest are almost colourless. As a rule, the pleochroism is faint, the colours varying between closely related shades of green. The broadest needles, however, occasionally show a pleochroism ranging through bottle-green and dark greyish-blue to colourless. All are perfectly clear and transparent, and entirely free from inclusions. This mineral is most probably a pyroxene, closely related to diopside or sahlite, which derived its green colour from a small percentage of Cr., and is in fact a chrome diopside. Unfortunately the scarcity of the material precludes a more searching examination of this mineral.

Rhombic pyroxenes and other accessory minerals.

I have already mentioned that a small number of brown crystals may be seen between the albite grains. These show numerous cleavage cracks, parallel to which straight extinction occurs. They consist of oblong plates of about ⅓mm. in length, the cleavage running parallel to the longer axis. This is most probably a rhombic pyroxene, not very rich in iron, very possibly bronzite.

Lastly, under a moderately high power, a very fine-grained aggregate may be seen, scattered here and there among the grains of albite, and running in fine strings into the hornblende crystals. This is always associated with a large number of the green to colourless augite crystals already described, which are particularly numerous in this aggregate. In thin sections, under a high power, these aggregates are seen to be clusters of minute radial fibrous spherulites, which between crossed nicols show, more or less distinctly, the characteristic black cross. The substance is colourless and gives very vivid polarisation colours, but cannot be more accurately determined.

From the above description, it is evident that the specimen under consideration is an albite-hornblende rock, in which the albite grains form a dense groundmass, containing porphyritic hornblende crystals. The remaining minerals have no particular share in the composition of the rock, and are therefore merely accessory constituents.

Hornblende-glaucophane schist.
General appearance.

4 *Hornblende-glaucophane schist.*—This specimen has a dark brown surface, in some places rough and in others smooth, but apparently not much rolled. It is a schistose rock of an intense emerald to grass-green colour, and bears a strong resemblance to smaragdite. A closer examination, however, at once reveals the fact that it represents an aggregate of greyish hornblende individuals, largely permeated by green enclosures, which impart to it its remarkable colour. The greyish portions pass in places into a deep green, but in other places again the green colouring matter is entirely absent. The hornblende individuals are most irregularly intermixed, and show no signs of definite arrangement. They attain a length of as much as 3, and breadth of as much as 2 cm. They have no definite crystalline outlines, but their cleavage is perfect, the angle between the two prismatic cleavages averaging 124½°. This angle could not, however, be accurately ascertained, owing to the frequent distortion of the prisms, which at times even causes a fringing of the ends. The orthopinacoid was observed on one of these prisms; it gives rather indistinct cleavage, and sharply and straightly truncates the obtuse prism edges. Thin splinters melt in the Bunsen flame; the thicker ones easily fuse before the blowpipe, forming a greenish-grey non-magnetic glass. It is not acted on by HCl., either before or after fusion. The s. g. of the *whole mass*—not that of the pure hornblende—was obtained from two pieces of the rock, the values being 3·113 and 3·126. I endeavoured to obtain the s. g. of the hornblende after removing the green parts, but it was not possible to separate the green colouring matter from the greyish hornblende.

Hornblende.

Chemical composition.

I could, therefore, only ascertain the chemical composition of the whole mass, and not that of the pure hornblende. As we have seen, however, that the whole rock consists chiefly of hornblende, containing only emerald-green crystals, the following figures will represent the chemical composition of the hornblende. Mr. R. Busz, who made analysis I, obtained the following results:—

	I.	II.
$Si O_2$	53·53	58·76
$Al_2 O_3$ $Cr_2 O_3$	9·10	12·99 ($Al_2 O_3$).
$Fe O$	4·02	5·84
$Ca O$	6·94	2·10
$Mg O$	15·94	4·01
$Na_2 O.$ $K_2 O.$	7·96	6·45 ($Na_2 O$).
Loss	2·95	2·54 ($H_2 O$).
	100·44	102·69

In the above analysis the very high percentage of alkali is remarkable: it consists chiefly of Na., containing only a small percentage of K.; $Cr_2 O_3$ and $Al_2 O_3$ were not separated. It seems, however, that no small quantity of $Cr_2 O_3$ must be present, for vividly green splinters give an undoubted Cr. reaction in the blowpipe flame. On the other hand, the grey hornblende hardly gives any tinge to the borax. The iron has been calculated as Fe O. According to the above analysis, the mineral proves to be an amphibole, containing a considerable amount of soda, thus resembling glaucophane, which, however, is distinguished by its dark blue colour from the mineral under examination. There are, however, grey varieties of glaucophane. The glaucophane most nearly allied to this mineral is that of Zermatt, the analysis of which is given under II. In both, the percentage of alkali, magnesia and iron very nearly agrees, as also the loss due to ignition. The difference in the percentage of $Al_2 O_3$ is rather more marked, while the difference in the silica is the most pronounced. There are, however, other glaucophanes, which, in this respect, closely resemble the mineral from Burma, *e.g.*, that from New Caledonia contains, according to Liversidge, only 52·79 per cent., while that from Sanjaron in Andalusia contains, according to Barrois and Offret only 47·4 per cent. of $Si O_2$. In the last mentioned variety, also, a low percentage of alumina corresponding to our 8·42 has been observed. From the majority of glaucophanes our mineral differs chiefly in the percentage of lime, for they do not as a rule contain more than 2 or 3 per cent. of CaO. Some, however, are known to contain a larger percentage, *e.g.*, that of Shikoko in Japan, which has a percentage of 4·80, while the glaucophane from Andalusia contains 12·90 per cent.

Glaucophane.

We are therefore undoubtedly entitled to consider this mineral as a glaucophane, inasmuch as its s.g. exactly corresponds with that of most glaucophanes, of which the s.g. ranges from 3·103 to 3·113, the average being 3·12, corresponding to the variety from New Caledonia. The low fusibility is another distinguishing feature. It is a remarkable fact that together with jadeite, which is a pyroxene, there should occur an amphibole, which, owing to its large percentage of Na. closely resembles it in composition. The strong pleochroism peculiar to the dark blue glaucophane is of course less pronounced in the mineral from Burma. In moderately thick slices, however, considerable differences of colour may be seen on rotation of the polariser. The vibrations parallel to $\mathfrak{a}$ are bluish-green, those parallel to $\mathfrak{b}$ greenish-brown and those parallel to $\mathfrak{c}$ yellowish brown, the absorption being $\mathfrak{b} > \mathfrak{a} > \mathfrak{c}$. In thinner slices the same colours appear, being, however, much paler, the differences being therefore less noticeable, while in very thin slices, they almost entirely disappear. The large extinction angle of the Burmese variety contrasts strongly with that of true glaucophane, in which it amounts to only a few degrees, while in the mineral from Tammaw it rises to 28°, a value much higher than that of other rock-forming amphiboles. Under the microscope, cross-sections show the characteristic prismatic cleavage of amphibole. In longitudinal sections the cleavages are very close together, thus producing an appearance of fibrous structure; and, as in the case of the prisms, these fissures are considerably distorted, while the ends are more or less fringed. There can be no doubt that these phenomena are due to the pressure which all the rocks of Tammaw have undergone. In longitudinal sections, also, may be seen an ill-defined transverse cleavage, running obliquely to the ordinary cleavage fissures. This most probably, as in other amphiboles, represents a cleavage parallel to $\bar{P}\infty$ $(10\bar{1})$, which is a very characteristic feature of glaucophane. Thus we see that the Tammaw mineral differs from true glaucophane only in its abnormal extinction angle.

Augite.

As already mentioned, the hornblende contains numerous fine needles or narrow prisms, which are always elongated in one direction. These are composed of a beautiful emerald-green augite, and produce the fine green colour of the rock, whenever they occur in any quantity. This colour we have already stated to be due to a small percentage of Cr., the very green grains giving a distinct Cr. reaction, while the grey crystals show no such reaction. These enclosures are very similar to those noticed above as forming part of the albite-hornblende rock. The latter, however, do not exhibit such a vivid emerald green, being rather of a bluish-green colour. As in the former case, their lateral boundaries are regular, but their ends are not infrequently fringed or pointed, in which case they assume the spindle-shape already described. The small needles are sometimes arranged very irregularly, but, as a rule, they lie parallel to the vertical axis of the amphibole prisms. The larger non-prismatic crystals form radiating groups, the ends of which are slightly curved and which, owing to their green colour, form a striking contrast to the colourless amphibole. Single crystals become alternately bright and dark in polarised light. The clusters, however, never extinguish entirely, for differently oriented crystals overlap each other. Cross sections show the typical form of augite, but prismatic cleavage is not well marked, the cleavage fissures being somewhat irregular. Transverse fissures, probably representing a transverse cleavage, as in diopside and other pyroxenes, are sometimes seen.

The angle of extinction is fairly high, but it is difficult to obtain measurements of it. Since the larger prisms never extinguish completely, while the smaller crystals are bounded by curves, straight cleavage-fissures being almost entirely absent. In some cases, however, I obtained values up to 50°. The pleochroism is very marked. Cross sections of moderate thickness, however, exhibit only slight differences of colour, the bluish-green remaining almost unchanged during a complete rotation of the polariser. On longitudinal sections, the differences are much more marked, the vibrations in the direction of the axis of elasticity being greenish-yellow, with at times a shade of uranium glass, while those normal to this axis are bluish green as in the cross-sections. Hence during rotation the colour varies between the above tints. Even in very thin slices, this is still visible; the very thinnest needles, however, having no distinct colour, have no pleochroism. The green material occurs in a different manner to that enclosed in the hornblende. The hornblende is frequently intersected by green strings, entirely composed of crystals of augite, as in the previous case. These are, however, of much smaller dimensions, and are, in fact, almost microlites. In rare cases circular clusters of such augite microlites have been observed filling up the fissures and other small cavities in the hornblende, while the larger augites, already described, were unquestionably developed at much the same time as the amphibole, in which they are enclosed; and there is no indication whatever that they were produced by subsequent alteration of the amphibole. It is a remarkable fact that all the Cr. has been taken up by the augite, while none is found in the amphibole.

Geological age.

From the above description of the rocks occurring in the jadeite mines at Tammaw, *viz.*, the jadeite, the olivine-serpentine, the albite-hornblende rock, and the amphibole-glaucophane-schist, we are enabled to form a clear conception of their nature. Noetling believes that the jadeite and the serpentine penetrate the surrounding tertiary sandstone, while with regard to the relations between the occurrence of the two other rocks and the jadeite, nothing is known. Noetling's view necessitates the assumption of an eruption of jadeite and another of olivine rock, following one another; but the petrological composition of these rocks is not favourable to such a view, which would include them among the tertiary eruptive rocks. Judging by the petrological characters, we must consider them as representing a system of crystalline schists.

Now there is no doubt that in former geological times olivine rocks were produced by volcanic eruptions. Nowhere, however, have rocks of this nature been found in beds of such modern date, being according to Noetling not older than of miocene age. Wherever tertiary masses of olivine are known to occur, as for example the enclosures in basalt, they are perfectly fresh, and show no signs of serpentinisation. I wish particularly to emphasize this fact, since the basalt which I shall presently describe, and which occurs in close proximity to the jadeite mines, has no geological connection with the jadeite, but is unquestionably an eruptive rock passing through tertiary strata. In this basalt the serpentinisation of the olivine has just begun, but has not progressed beyond the first stages, while such a complete alteration as that exhibited in the above specimens is characteristic of all ancient olivine rocks—such as palæopikrite—and, as I have already observed, of the crystalline schists.

To consider the jadeite as an eruptive rock would be entirely unjustifiable: for neither in the older nor yet in the more recent series of eruptive rocks has any rock of the nature of jadeite been found. In Turkistan, however, it has been proved to be imbedded with nephrite in the crystalline schists (gneiss and mica schist), and belongs to that series.

The two other rocks also offer material proof in favour of this view, for it is highly probable that the glaucophane-schist is one of the crystalline schists. Hitherto, glaucophane has been found only in gneissic rocks and mica schists, no instance having been recorded of its occurrence in eruptive rocks, much less of its entirely composing such rocks. The same holds good for the albite of the albite-hornblende rock. This mineral frequently occurs as a component part of the crystalline schists, but hardly of eruptive rocks. The peculiar aggregation of the albite grains is in perfect harmony with this view, for such a structure would be by no means remarkable in a crystalline schist. I am therefore of opinion that the jadeite and the other rocks must be looked upon as part of the series of crystalline schists, overlaid by tertiary beds and probably denuded by erosion. It is most probable that they were raised to their present level together with the surrounding tertiary rocks, when these latter were subjected to folding. I have repeatedly laid stress on the fact that these rocks must have been subjected to great pressure, which can only be accounted for by folding. I do not assert for a moment that the above arguments are absolutely convincing, but they certainly support the view which best accords with the petrological evidence, while the stratigraphical conditions observed by Noetling in the mines at Tammaw fully bear out this view. Further observations, however, with regard to the geological conditions of that country, will certainly decide the question. On the geological map of Burma, west of the Irrawaddi, even west of Mogaung, towards Tammaw, sub-metamorphic rocks are indicated; while crystalline limestones, probably of silurian age, extend to within about two miles of the eastern side of the jadeite mines.

In conclusion, I wish to mention a rock which, although not belonging to the series described from the jadeite mines, has been found on a hill four miles east of Sanka village. It is an excellent felspar-basalt, with blackish-grey fracture, and brown weathered surface. Under the microscope, the felspar—plagioclase—forms a crowd of minute lamellæ, in which only very few individuals are twinned, while a very small number of the crystals are somewhat larger. The felspar crystals form the groundmass in which all the larger constituents of the rock are porphyritically imbedded.

Basalt.

The augite is of a very light yellowish-green colour, without noticeable pleochroism, but with oblique extinction as is usual in basaltic augites. The crystals, which are regularly bounded by straight lines, are usually of considerable size. There are, however, smaller crystals which in their dimensions very nearly approach the lamellar felspars. These small augite crystals form part of the groundmass together with the felspars, but they are not nearly so numerous as the latter. They are much more sharply and regularly bounded than the larger crystals, and probably represent a later generation of augite. As a rule, they are single, but twins are occasionally seen parallel to the orthopinacoid, and not infrequently polysynthetic. Cruciform twins appear to occur, but I cannot state with absolute certainty that any regular intergrowth takes place. The augite, like the felspar, is perfectly fresh, and both are fairly free from foreign enclosures of all sorts. Magnetite, however, generally very regular in shape, is not infrequently included in the augite. Olivine usually forms the largest crystals; it is either perfectly fresh or intersected by a few cracks along which serpentinisation has just set in, only small progress, however, having been made in this direction. It also contains inclusions of magnetite grains. A few dark brown transparent grains of picotite occur, while liquid enclosures containing moveable bubbles are frequently seen, arranged in the well-known zones. Magnetite is fairly common, and usually forms well-defined crystals of considerable size. These crystals sometimes occur singly, and sometimes in larger and regularly-arranged groups. They are partly imbedded in the groundmass between the felspar and augite microlites, and partly occur as enclosures in the larger augites and olivines. As already stated, I consider some of the darker brown and transparent enclosures in the olivine to be picotite. A number of long, colourless needles with straight extinction, and sometimes grouped in clusters, are crystals of apatite. No other minerals have been observed, while glass, in particular, is entirely absent, not a trace of it having been discovered.

The basalt is therefore holo-crystalline and falls under class II of Zirkel's classification, the members of which group are distinguished by a fine-grained, microscopic groundmass, which is crystalline throughout or only contains a small quantity of magma in which larger crystals—in this case augite and olivine—occur. Or if we adopt Rosenbusch's classification, we must describe it as a holo-crystalline porphyritic basalt, in which, notwithstanding the enormous number of plagioclase lamellæ forming the groundmass, no larger plagioclase crystals appear, as is more usually the case. Warm HCl affects the rock but slightly, while cubes of NaCl are not formed after evaporation.

On the Geology of the Tóchi Valley, by F. H. SMITH, A.R.C.S, *Assistant Superintendent, Geological Survey of India* (with pl. 3).

Towards the end of February 1895 I received orders to join the delimitation party at work in the Tóchi valley. A geologist was specially required to ascertain, if possible, whether the reported occurrence of copper and iron in the hills south of the Tóchi river, and between it and the Khaisor, was of economic importance.

Unfortunately, when I received my orders, I was engaged in field-work amongst the southern spurs of the Sulaimán range in Baluchistán, and by the time I caught up the Tóchi column that part of the delimitation work situated in the Tóchi hills had been completed, and I never had an opportunity afterwards of seeing more than the northern or Tóchi flanks of the hills.

Copper and iron.

I may say at once that, as far as I could observe, the hills between the Tóchi and Khaisor rivers contained no minerals of any economic importance. I have not met with any trace of copper, or mineral containing copper during my march along the Tóchi and one or two tributary streams.

The Waziris are said to work and smelt iron ore to a considerable extent in the hills to the south of the Tóchi; and the number of native-made knives seen all over Waziristán shows that there must be a considerable iron industry. The majority of the knives are made of very soft iron, and their value, when sold to Europeans, seemed to be from 2 or 3 rupees each; smaller knives of mottled native steel are fairly common, the price of which seems to run up to anything under 25 or 30 rupees, according to the appearance of the intending purchaser.

The only place where I found any traces of iron ore was Mirán Sháh. There I found several concretions of very pure soft hæmatite, in middle or lower eocene sandstone beds. These beds have *roughly* a north and south strike in this neighbourhood; to the north the series forms the Laram hills, while to the south the hill-country between the Tóchi and the Khaisor, or Khasora, is mainly composed of these same rocks. It is very probable that the iron ore supply is derived from this pure concretionary hæmatite, which could easily be found in sufficient quantities for the manufacture of knives and other small implements, but which would probably run out at once if worked to any great extent. Even if pure hæmatite were found in greater abundance, as is constantly the case in other parts of India, the total absence of fuel would render it useless in this valley.

Although my march up the Tóchi was not very successful from an economic point of view, it was none the less interesting geologically, especially as I traversed new country.

Topography.

Marching from Bannu up the Tóchi valley, one enters the outer range of tertiary hills near Tóchi village, at a height of about 1,000 feet above sea-level. From here to Dotoi, the farthest point I reached, is about 60 miles in a straight line, and rather more along the river bed which runs almost due east and west. At Dotoi the height is about 5,000 feet, and the higher peaks around run up to 10,000 feet. To the west of the outer hills mentioned above, which run roughly north and south, the river bed traverses two

wide plains, the Idar Khél and Idak valleys. Both plains are bounded north and south by hills, which close in to the west of Idak, above which the river-bed lies between irregular hills, forming a more or less narrow valley.

I was able also to march up a tributary of the Tóchi, the Kazha nala, which rises on the Luara plateau under Charkhiaghar to the north of Dotoi, and runs nearly parallel to the Tóchi till it joins it near Pakki Kôt.

Geology.

As the newer rocks present none of the difficulties which are met with in the older rocks which I saw, I will describe the section in descending order. Roughly speaking, the younger rocks are found in the eastern outer ranges, which rise from the Bannu plain, and older rocks appear in the interior to the westward.

The rocks in this outer range—the Shinkai hills—showed a most striking similarity in composition and arrangement to those of the Fort Munro range, south-west of Déra Gházi Khán. This latter range, rising from the Indus plain, presents a perfectly normal section of rocks which dip steeply eastwards under the Indus plain; from upper siwalik conglomerate in the outer ranges, through lower siwalik, upper, middle, and lower eocene rocks, with beds of probably cretaceous age at the base. Having just traversed the Fort Munro range, the similarity between it and the Shinkai range rising from the Bannu plain, some 200 miles to the north, appeared all the more striking to me. Evidently the same, or nearly the same, series of tertiary rocks have been disturbed and folded in the same manner, and for a distance of hundreds of miles along the frontier hills west of the Indus plain. Taking the normal section of the Shinkai range from west to east, nearly the same series of beds is met with.

Siwaliks.

The outermost range commences two or three miles to the west of Tóchi village, where the massive conglomerates and grits of the upper siwaliks dip gently to the east under the Bannu plain. The dip becomes steeper further west, and in the highest ridge of these hills the rocks dip very steeply, still eastwards, till along the bank of the Tóchi river it becomes vertical; this dip is maintained westwards throughout the lower siwaliks and upper nummulitics at least. The thickness of these conglomerates must be great, and is probably several thousand feet, but the lower siwalik beds are of even much greater thickness. In the Saidgi valley the rocks change from conglomerate (east) into an immense thickness of sandstones and shales (west). The conglomerate passes gradually and perfectly conformably into finer sandy strata, which at once become interbedded with beds of shale. The lower siwalik beds consist entirely of grey sandstones and red shales; the latter predominate in the upper beds, but give way lower down to soft sandstone beds, which contain no shale bands at the base. The dip is vertical throughout the whole section of these beds across the Saidgi valley and up to the highest ridge of the hills westward. The strata appear not to be crushed to any extent, but are exposed as a perfectly normal section, with an outcrop of fully 2 miles in breadth, which gives the lower siwalik beds the immense thickness of 10,000 feet. I could find no trace of fossils in either the shales or sandstones.

Upper nummulitic.

Along the ridge of the hills west of Saidgi there runs a bed of white hard limestone, under 200 feet in thickness. The dip is vertical, and at Shinkai in the river bed the exact thickness is 170 feet.

The limestone is full of fossils, the harder bands being almost made up of *nummulites* and *alveolinæ*, while some softer muddy bands are full of gastropods and bivalves, with which I found part of a well preserved crab.

The junction of this white limestone with the overlying grey siwalik sandstone is clearly seen in the river bed. In position they are perfectly conformable; the white limestone is very nodular, so that the upper surface is not quite smooth. The sandstone fills up the irregularities, and the bedding of both is perfectly parallel: the sandstone contains many limestone pebbles for about 2 feet from the junction, but the parallelism appears perfect. The junction of this upper nummulitic limestone with the lower beds is not so well seen, but the white limestone appears to rest conformably on the soft shale beds below. To the north of Sherani, upper nummulitic rocks occupy a considerable area, forming a flat basin north of the Tóchi. The rocks consist of white limestones and interbedded light green shales; the limestone is identical with that at Shinkai. The thickness of the whole exceeds that of the rocks at Shinkai, but the base beds rest on rocks so much disturbed by igneous intrusions that I could make no very definite observations on the lower beds.

Lower nummulitic.

Below the white limestone comes a thickness of 400 to 500 feet of olive green shales, very like the 'ghazij' shales of the Quetta area, which are of middle nummulitic age; at the base of these I observed some red shale bands, below which come 200 to 300 feet of shales, interbedded with shaly limestone and limestone breccia. The breccia contains many fossil organisms, but I have not found any nummulites amongst them; a fossil fruit was found in the associated shales, but nothing could be seen in the shaly limestone.

These shaly beds down to this point may probably represent the middle nummulitics, but they pass so imperceptibly into lower rocks that no distinct division can be made. Below the limestone breccia band the shales become interbedded with sandstones and calcareous sandstones, and dip again steeply to the east. This series of rocks continues from Shinkai to the Idar Khél plain on the west, the dip lessening towards the east on nearing the plain.

The main mass of the rocks consists of soft shales, greenish brown to red in colour, with frequent partings of softish sandstone, buff to brown inside, but always weathering a shiny black on the surface. Some beds appear to have been altered into red coloured porcellanic, shaly limestone bands. Near Idar Khél the sandstone bands, nearly white in colour, increase in size and contain pure limestone bands, layers of sandstone and limestone alternating several times in the course of 2 or 3 feet.

In some places this series is considerably contorted, but on the whole there is a steady easterly dip throughout. There must be several thousand feet of these rocks visible in the section along the river bed. I may mention here that the black weathering of the sandstones and calcareous sandstones is very typical of middle and lower eocene rocks in eastern Baluchistán. In the calcareous sandstones there are traces of organisms, apparently *foraminifera*, but I found no fossils in any of the other sandstone or shale bands.

The Idar Khél plain is cut out of a flat anticlinal of these lower eocene rocks; in the hills east of Idak they dip again gently westwards, but here the predominance of sandstone bands is changed to one of calcareous and limestone bands, which are remarkable for the quantity of corals in them. These beds, hard grey limestones and shales with some sandstone bands, form the hills south of the Tóchi as far west as Mahomed Khél, and to the north of the Tóchi from Mahomed Khél across to the Laram hills, and from thence down to the hills surrounding the Idak plain.

Mesozoic.

The range of hills between Idak and Mirán Sháh is formed by an anticlinal ridge which approximately strikes north and south, and which is composed of these lower eocene beds. In the core of the anticlinal a considerable thickness of massive dark grey limestone is exposed, in which I could find no fossil remains; the age of this limestone is therefore doubtful, and there is no evidence of any kind to show whether it belongs to the lowest tertiary or upper mesozoic age.

Dotoi beds.

The middle and lower eocene beds between Shinkai and Mahomed Khél are conspicuous by the general absence of undoubted nummulites: corals and the broken shells of bivalves are abundant, but *foraminifera* only occur rarely and then the traces are badly preserved. Round Dotoi, however, beds of apparently lower eocene age appear, yellow limestones with interbedded blue slaty shales, of which the limestone bands are full of fine nummulites of all sizes. These beds have no resemblance to the very white limestones and light green shales of the upper nummulitics, and very little more resemblance to the non-nummulitic rocks round Idak; in fact they show no resemblance to any of the rocks seen in the Shinkai hill section. This may be explained by the amount of igneous alteration which has taken place in the neighbourhood, and which has effaced all evidence of connection between the Dotoi rocks, the upper nummulitics north of Sheranni, and the lower nummulitics east of Mahomed Khél.

Igneous intrusion.

One is much struck on marching up the Tóchi river bed by the great quantity of pebbles and boulders of igneous rocks met with *en route.* The majority of the pebbles, even at Tóchi village, are of diorites, gabbros, and basic rocks. No indication of their being anywhere *in situ* is met with till one arrives within about 3 miles of Mahomed Khél. Here the lower eocene limestones and shales are seen to rest abruptly, but conformably on a series of beds, and are doubtless part of the latter, which are altered by igneous action, but with evidence of having been interbedded with igneous rocks, which in many cases form massive intrusions in the former. This facies of beds covers the country between Mahomed Khél and Dotoi, though it is overlaid by upper nummulitic beds north of Sheranni.

The igneous intrusions are invariably of the more basic rocks. I never found a trace of any acid rock, but diorites are very common, and they, as well as more basic forms, appear to pass gradually into the rocks which they penetrate partially. As generally happens, the beds are altered to such an extent near the junction, that no definite line can be drawn between the true shales on one hand and the true crystalline rock on the other. Throughout the whole area of igneous disturbance I never found anything but shaly beds associated with the igneous rocks.

Age of igneous series.

In some cases the shales have undergone very slight alteration only, but unfortunately I have not found any traces of fossils in beds connected with the igneous rocks, so the only clue to the age of these beds rests on their relative position to other beds. On the west the igneous series is overlaid by the lower nummulitic Dotoi beds, with the bedding more or less parallel. On the east the Idak series of lower eocene rocks rests conformably on altered shale beds with igneous intrusions. Upper, and perhaps middle, nummulitic beds directly overlay the igneous rocks between these two junctions; the disturbance in the basal beds makes it impossible to see from a distance what connection there is between the upper nummulitics and the igneous series. It is singular that nothing but shaly beds should be found within the area of igneous disturbance. The natural conclusion to be drawn seems to be the supposition that igneous action, in the form of intrusions and deposition of ash beds, began some time before the beginning of the tertiary period; and lasted, with occasional variations causing interbedding, up to the end of middle eocene times.

Series.

The intrusive masses vary a good deal in composition. I found various forms of diorite, but the greatest variety seemed to be in the gabbros, which pass gradually into hypersthene (and diallage) rocks. Some pebbles, of what appeared to be amygdaloidal basalt, occurred in the river bed, but I never found this rock *in situ*. From the diversity of these rocks, ranging from intermediate to basic, and probably ultrabasic forms, coupled with their interbedding with shales and possibly other rocks of eocene age, it seems very probable that this series may correspond to the widespread formation of shales and igneous rocks which form large areas in Baluchistán; the Kójak shales are typical for this lithological formation, which also ranges from the later cretaceous to middle eocene times.

Description of sections.

In the absence of an accurate map, the accompanying sections (pl. 3), which are drawn approximately from east to west across the general strike of the beds, may give some idea of the arrangement of the rocks. The three sections, which are drawn to natural scale of 1 inch = 1 mile, follow the Tóchi river, mostly through the hills directly to the north of it. They do not conform quite to a straight line from east to west, but yet so closely, that they may be taken to represent a continuous section from the Dotoi country to the Bannu plain.

Section I.—To the west the Dotoi beds, considerably disturbed and contorted, form the greater part of the country, and rest near Dotoi village on the igneous series. The junction beds show a good deal of disturbance, as is natural in the immediate neighbourhood of igneous intrusions, and it is doubtful what connection there is between the beds. To the east there appears a flat basin of upper nummulitic beds, quite unaltered, composed of white nummulitic limestone, interbedded with light green shale beds. The base beds of this series is seen here and there to be drawn into the sphere of igneous action, showing that the disturbance lasted up to middle eocene times at least.

Section II.—The Idak series of lower nummulitic beds rests on the igneous facies, just north of Mahomed Khél. Igneous disturbance seems to have ceased half way through lower eocene times, leaving the upper half to the east unaltered. The only break in these beds to the east, as far as Idak, occurs in the anticlinal ridge of older limestone between that place and Mirán Sháh.

Section III.—The Idak beds form a flat broad anticlinal, which is mostly hidden under the Shamalara plain, between Idak and Shinkai, where they are seen to dip conformably under the upper nummulitic band of limestone, and this is followed normally by the lower and upper siwalik beds, which disappear finally under the Bannu plain.

On the existence of Lower Gondwanas in Argentina, by DR F. KURTZ[1]; *translated by* JOHN GILLESPIE.

I. INTRODUCTION.

As long ago as 1875, Dr. Luis Brackebusch had described a fossiliferous formation which occurs at Bajo de Velis, and on which he has written several papers. He says[2]: "Having received from Mr. D. G. Avé Lallemant some interesting data on the existence of fossiliferous shales in the Cautana valley, I proceeded to that locality, and was not a little surprised to find some fossiliferous beds at Bajo de Velis (about a league from the entrance to the Cautana valley). This exceedingly interesting find detained me a couple of days, and I ascertained that these beds, which consist of conglomerates and argillaceous shales, had only a small vertical and horizontal extent and were unconnected with the high cliffs of the Cautana valley; they form old lake deposits in which a large quantity of plant remains have been inclosed . . . there are no animal remains found in this place." The fossils which Dr. Brackebusch sent to Dr. A. Stelzner are too badly preserved for determination, and consist solely of casts of wood.

Later on, a resident of the place, Sr. Lucio Fúnes, quarried slate for a church at Bajo de Velis, and Sr. Bonaparte, who superintended the work was the first who discovered well-preserved fossil plants, amongst them *Neuropteridium validum*, Feistm., and *Sphenozamites multinervis* non-spec. Señor Bonaparte presented the collection to Sr. D. Gualterio G. Davis, Director of the Meteorological office of Argentina, who handed them over to me for description. In 1883 Señor D. Francisco P. Moreno, Director of the Museo de la Plata, added to this collection from Bajo de Velis, which has enabled me to establish the age of the fossiliferous shales of that locality.

In describing these plants, I have followed the system adopted by W. Ph. Schimper and A. Schenk (in the 2nd part of the Handbuch der Palæontologie by K. A. von Zittel).

II. DESCRIPTIVE PART.

Dr. Kurtz describes 8 species, amongst which there are 3 new species or rather varieties of well-known Gondwana fossils.

III. SUMMARY.

The fossil flora of the argillaceous shales of Bajo de Velis, as far as known at present, consists of the following species:—

Neuropteridium validum, Feistm.
Gangamopteris cyclopteroides, Feistm.
Equisetites Morenianus, Kurtz.
Sphenozamites multinervis, Kurtz.
Noeggerathiopsis, Hislopi (Bunb.) Feistm.
N. Hislopi, Feistm. var. *subrhomboidalis*, Feistm.
N. Hislopi, Feist. var. *euryphylloides*, Kurtz.

[1] Published in the Revista del Museo de la Plata, Vol. VI, p. 117 ff.

[2] Boletin de la Academia Nacional de Ciencias (Córdoba), Vol. II, 1875, p. 188; quoted by Dr. A. Stelzner in Beiträge zur Geologie und Palæontologie der Argentinischen Republik, part I, 1885, pp. 75-76.

All these species are new to Argentina, and partly also to science in general. The small number of specimens collected does not enable us to form an idea as to the relative frequency of the various species, but nevertheless it is apparent that the commonest form met with is *Noeggerathiopsis.* A similar flora is found at the Cape of Good Hope (Ekka-Kimberley beds), in Peninsular India (Kaharbari beds), in Australia (Newcastle beds, Bacchus-marsh sandstone), and in Tasmania

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Neuropteridium validum, Feistm	Neuropteridium validum, Feistm.	
Glossopteris communis, Feistm.		
G. indica, Fstm. . . .		
		Glossopteris Browniana, Brongn.
G. damudica, Fstm.		
G. decipiens, Fstm..		
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides Fstm.	
G. cylopt. var. attenuata, Fstm.		Gangamopteris cyclopteroides var. attenuata, Fstm.
G. cyclopt. var. areolata, Fstm.		
G. cyclopt. var. subauriculata, Fstm.		
G. buriadica, Fstm.		
G. major, Fstm.		
G. angustifolia, McCoy.		
Sagenopteris (?) Stoliczkana, Fstm.		
Schizoneura gondwanensis, Fstm.		
Sch. cf. Meriani Schimp .		
Vertebraria indica, Royl. .		
	Equisetites Morenianus, Kurtz.	
Glossozamites Stoliczkanus, Fstm.		
	Sphenozamites multinervis, Kurtz.	
Noeggerathiopsis Hislopi, Fstm	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.	N. Hislopi var. subrhomboidalis, Fstm.	
	N. Hislopi var. euryphylloides, Kurtz.	

(Mersey coalfield). Of all these floras, that of the Karharbari beds of the lower Gondwanas in India is closest related to the specimens found at Bajo de Velis, as may be gathered from the accompanying table, which contains a comparison of the various floras mentioned above.

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Sphenopteris lobifolia, Morr.		
S. alata Brongn. et var. exilis Morr.		
S. germana, McCoy.		
S. hastata, McCoy.		
S. plumosa, McCoy.		
S. flexuosa, McCoy.		
Glossopteris communis, Fstm.		Glossopteris communis, Fstm.
G. Browniana, Brongn.		G. Browniana, Brongn.
G. parallela, Fstm.		
G. linearis, McCoy.		
G. gangamopteroides, Fstm.		
G. ampla, Dana.		G. ampla, Dana.
G. reticulum, Dana.		
G. elongata, Dana.		
G. cordata, Dana.		
G. spathulato-cordata, Fstm		G spathulato-cordata, Fstm.
		Gangamopteris cyclopteroides, Fstm.
		G. cyclopt. var. attenuata, Fstm.
		G. cyclopt. var. subauriculata, Fstm.
	Gangamopteris angustifolia, McCoy.	Gangamopteris angustifolia, McCoy.
	G. obliqua, McCoy.	G. obliqua, McCoy.
	G. spathulata, McCoy.	G. spathulata, McCoy.
Gangamopteris Clarkeana, Fstm.		
Caulopteris (?) Adamsii, Fstm.		
		Tasmanites punctatus, Newt.
Phyllotheca australis, McCoy.		Phyllotheca australis, McCoy.
Vertebraria australis, McCoy.		
Podozamites elongatus (Morr.), Fstm.		
		Noeggerathiopsis Hislopi, Fstm.
Noeggerathiopsis media (Dana), Fstm.		

Kaharbari beds (India).	Bajo de Velis (Province De San Luis, Argentina).	Ekka-Kimberley beds (Cape).
Carpolithes Milleri, Fstm. Euryphyllum Whittianum, Fstm. Voltzia heterophylla, Brongn.		
Samaropsis sp.		

The following may be deduced from this table with regard to the fossil plants of Bajo de Velis :—

Neuropteridium validum, Fstm., is found in the Kaharbari beds of Bengal where it represents one of the most frequent and most characteristic types. It is noteworthy that this beautiful fern is confined to one horizon only (sandstone beds) of Bajo de Velis.

Gangamopteris cyclopteroides, Fstm., (5 varieties) and 4 other species are the commonest and predominating forms which occur in the Talchir-Kaharbari beds; in the next succeeding horizon, the Damuda division, only some small forms of this genus survive, but they disappear completely higher up. In Africa *Gangamopteris cyclopteroides* has been found only in the lower beds of the "Karoo" formation (the "Ekka-Kimberley" beds) and this is the only species of *Gangamopteris* known in Africa. In Tasmania *G. cyclopteroides* has been found with its varieties, *G. attenuata* and *G. subauriculata*, all in the Mersey coalfield. *Equisetites morenianus*, Kurtz, may be compared with the various remains of the families of the *Equistaceæ*, and of the Schizoneuræ found in the Talchir Kaharbari beds, and very probably belongs to the genus *Schizoneura*, which would clear up an important point connected with the Damuda-Panchet system; in Australia the genus *Phyllotheca* is represented in the group of the Schizoneuræ. *Sphenozamites multinervis*, Kurtz, stands isolated and cannot be compared with forms elsewhere.

Noeggerathiopsis, Hislopi, Fstm., occurs in the Talchir-Kaharbari beds and in the middle Gondwanas (frequently at Damuda and South Aurunga); in the upper Gondwana (Rajmahal series) no species of *Noeggerathiopsis* exist (although they occur at Tonkin). In Africa *N. Hislopi*, Fstm., is only seen in the Kimberley beds, and in Tasmania the species has been found in the Mersey coalfield.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari bed.
Neuropteridium validum, Fstm		Neuropteridium validum, Fstm.
Gangamopteris cyclopteroides, Fstm.	Gangamopteris cyclopteroides, Fstm. var.	Gangamopteris cyclopteroides, Fstm.
Equisetites Morenianus, Kurtz.		
Sphenozamites multinervis,		

Newcastle beds (New South Wales).	Bacchus-Marsh Sandstone (Victoria).	Mersey Coalfield (Tasmania).
Brachyphyllum australe, Fstm. (?); cf. Schimper-Schenk, Palæophytologie, pp. 331, 336).		

where it is associated with another species of the same genus, *N. media* (Dana), Fstm. This last and two more species have been likewise found in New South Wales.[1]

The better to compare the relations which exist between the fossil flora of Bajo de Velis and the plants of the other areas, which we have had under consideration, I have compiled a table of the data available.

From the data given in the following table it may be concluded that the fossil flora of Bajo de Velis belongs to the same geological horizon which holds the other 5 plants mentioned, and that its prototype is the flora of the Talchir-Kaharbari beds of the lower Gondwanas. The palæophytologist O. Feistmantel has already discussed at some length the relation which the lower gondwanas, and the strata in Africa and Australia, occupy to the recognized horizons, especially those of Europe, and has arrived at the conclusion that the formations in question belong to the Permian system, that is to say, that they represent the close of the palæozoic group, a conclusion which several Australian geologists have endorsed, and which in my opinion may be generally adopted with reference to the age of the beds in Argentina[2] :—

[1] The genus *Glossopteris*, so abundantly represented in the various strata of the Gondwana system in South Africa, India and Australia, where it appears for the first time in the upper carboniferous strata (Queensland) and rises to the upper Trias or the lower Jurassic (' Jubbulpore group ") is completely wanting in America (as also in Europe); *Glossopteris* is chiefly distinguished from the genus Gangamopteris by the existence on its fronds of a median vein, which character is completely absent in *Gangamopteris*.

[2] It must be mentioned here that this view had practically been adopted by the members of the Geological Survey of India some time before Dr. Feistmantel would admit it himself. (Director Geological Survey of India.)

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Gangamopteris (1 spec.).	Gangamopteris (3 spec.).	Gangamopteris cyclopteroides Fstm., cum var. et. 3 spec. alt.

Bajo de Velis.	Ekka-Kimberley beds.	Kaharbari beds.
Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.	Noeggerathiopsis Hislopi, Fstm.
N. Hislopi var. subrhomboidalis, Fstm.		N. Hislopi var. subrhomboidalis, Fstm.
N Hislopi var. euryphylloides, Kurtz.		

Up to. date we know of three rock-formations in Argentina which have yielded fossil plants. The first is that of Retamito in San Juan, which corresponds to the lower carboniferous (Culm) as Dr. L. Szajnocha [1] has already shown; then follows the flora of Bajo de Velis which has no species in common with the preceding formation nor with the following series. The latter occurs in the neighbourhood of Cacheuta, Challas and Uspallata in Mendoza, at Mareyes in San Juan, and in the Escalera de Famatina in La Rioja. The fossils found at the latter places belong to completely different flora, which Professor H. B. Geinitz has already determined as belonging to the rhætic,[2] a conclusion confirmed by Dr. A. Stelzner [3] and also by Dr. L. Szajnocha[4].

To the same epoch belong the fossil plants, which are found in the Stormberg beds (Upper Karoo) of South Africa; in the Tivoli-Ipswich beds of Queensland; in the Wianamatta-Hawkesbury beds of New South Wales; and in the Jerusalem beds of Tasmania: that is to say, that these fossil plants occur in horizons between the upper triassic and lower jurassic systems. In India the lower beds of the Rájmahál series (Upper Gondwanas) correspond more or less to the rhætic system.

In the following table I have arranged the plant-bearing beds of Argentina according to their geological horizons:—

Series of beds at Cacheuta, Challas, Uspallata, Marayes, Escalera de Famatina.	Rhætic.
?	Trias.
Bajo de Velis series.	Permian.
?	Upper carboniferous.
Retamito series.	Lower carboniferous (Culm).

[1] Revista, Vol. VI, p. 119; see also Stz. Ber. Kais. Akad. d. Wissensch. Wien, Vol. C, pt. 4, p. 203 (Dir., G. S. I.).

[2] Ueber rhætische Pflanzen und Thierreste in den Argentinischen Provinzen La Rioja San Juan und Mendoza: 1876 (Palæontographica Suppl. III.).

[3] Beiträge zur Geologie und Palæontologie der Argentinischen Republic, I: 1885, pp. 68-82.

[4] Ueber fossile Pflanzenreste aus Cacheuta in der Argentinischen Republic. Sitz. Ber. Kais. Akad. Wiss. Wien., Vol. XCVII, pt. 1, 1888, pp. 219-245.

Newcastle beds.	Bacchus-Marsh Sandstone.	Mersey coalfield.
Noeggerathiopsis (1 spec.).		Noeggerathiopsis Hislopi, Fstm.

Note by the Director, G. S. I.—The evidence afforded in the above paper has such a strong bearing on the age and relations of the most important of all our rock-formations of India, namely the coal-bearing Gondwanas, that it appeared advisable to have it translated from the Spanish original, which has been ably done by Mr. John Gillespie, to whom our acknowledgments are due.

One of the chief points of interest in connection with the discovery of Gondwana plants in Argentina lies in the fact that there we have an unquestionable lower carboniferous series (Retamito) in the neighbourhood of which (and probably unconformably to it) a series of beds is found, which contains well known lower Gondwana species of plants, thereby limiting the geological range of the lowest beds of it, at all events to upper carboniferous at most, which is a further confirmation, long ago and independently arrived at by the authors of the "Manual" (1st edition) and generally adopted by the Geological Survey of India.

Notes from the Geological Survey of India.

I. *Central India, Rewah.*—Mr. Oldham with Mr. Datta have continued their surveys in Rewah, and some of the results of their work have already been noticed in my annual report and in the "Notes," Records, part 2; with regard to the Vindhyans and underlying rocks no specially new facts have come to light; but, on the other hand, Mr. Oldham has latterly been engaged in the survey of a patch of Gondwanas, which contained several rather fair coal-seams, though few over three feet in thickness. The total extent of the surveyed area of the coal-measures is about 200 square miles, and it is situated east of the Mohan river, shown in sheet 476 of the Rewah survey.

Near their western limit they are covered by red ferruginous sandstones and shales, whose extent has not been determined. The Barakar age (already determined correctly by Mr. Smith) is clearly shown by the fossil contents, amongst which are *Vertebraria, Glossopteris, Schizoneura,* etc. Two coal-seams of 6 feet and 5 feet 6 inches thickness were found by Mr. Oldham; the former is 1½ miles south-west by west of Ujeini, the latter, 2 miles north of Amlia, both places near the eastern edge of the standard sheet 476.

II. Madras.—Mr. Middlemiss continued his researches in the Salem district and reports in February.

(1) *Magnesite and ultra-basic rock of Valaiyapaddi*.—The magnesite is present in very small quantities. The rocks associated with it entirely resemble those at the north-west end of Kanjamallai, so far as their appearance in the field goes. Forming a long low ridge, running east and west from Valaiyapaddi, there are interesting examples of the above type in close association with a very acid rock, namely, a coarse graphic granite composed almost entirely of pink orthoclase and quartz. Both rocks are intrusive among the basal gneisses of that area in parallel lines. Some good instances of this are to be found west of Valaiyapaddi. The graphic granite was probably intruded last.

(2) *Charnockite, south of Salem.*—Between Muttu Kalipatti and Salem on the Namakal-Salem road a great exposure of charnockite occurs. From its position, strike, and general appearance it is a continuation of the Shevaroy Hills massif.

(3) *Chalk Hills.*—The final few days spent at the Chalk Hills enabled me to secure some "camera" sketches and photographs. As a whole, the aspect of each magnesite area is that of a series of concentric ellipses (roughly speaking) of rocks of varying composition and basicity. At the centre of each area occurs the chromite in veins among the dunite and serpentine; surrounding this is a paler dunite zone (almost pure olivine, or partly or wholly converted into magnesite). Surrounding this again is a small ring of rocks containing olivine and pyroxene with sometimes biotite. Surrounding this at certain points come rocks like the last, but with felspar and quartz in small quantities. Finally, surrounding the whole area come great ridges of hornblende-garnet rocks set among and with the ordinary gneisses of the country.

(4) *Corundum localities, Coimbatore District.*—The corundum localities visited in Coimbatore embraced Selengapalaiyam near Kavanthapatti where the mineral is only sparingly found and picked up from the surface after heavy rain. It is similarly found at Gopichettipalaiyam in one small field. The locality of Siva Mallai is the best that I have yet seen. The mineral is regularly worked for and occurs as large hexagonal prisms scattered about in an extremely coarse biotite granite with pink felspar. The latter follows along the north-west side of a range of low gneiss hills, a continuation of the Siva Mallai. The corundum is chiefly found on the margins of the granite veins.

III. Baluchistán.—During February Mr. Smith examined the high range between the Lúni plain and the Zhób territory. This range is apparently formed of massive jurassic limestone, containing ammonites; its thickness is very great, and in the Wat pass, which leads through the centre of the range, it is quite 2,000 feet, all within sight, and the base is not exposed.

This grey, massive limestone is overlaid by the neocomian belemnite beds, consisting of yellowish to pink, light green and white shaly limestones and shales,—conformably apparently. The entire area near Mekhtar is formed of these beds, which yielded belemnites in abundance besides some ammonites.

This neocomian horizon is overlaid by a great series, which Mr. Smith was enable to divide further, but which seems to have varied a good deal lithologically; the middle of the series apparently contained nummulitic limestone beds, and the uppermost beds were capped by the white nummulitic limestone of the Spintangi beds. Some of the beds of this great series appear to be derived from volcanic material, and even basaltic rock was met with.

There can be little doubt but that this sequence of beds represents the great belt of strata, which extends from south of Hindu Bágh, north of the Loralai hills along the southern side of the Zhób valley, and which show such a well pronounced flysch character. The lowermost beds are upper cretaceous, whilst the whole lower and middle nummulitic division of the tertiary system is represented.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

CALCUTTA;
The 1st August 1895.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig 6.

ROCKS FROM THE GIRIDIH COALFIELD.

Photographs by W. J. Simmons & T. H. Holland.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1895. **November.**

On the Igneous Rocks *of the* Giridih (Kurhurbaree) Coalfield *and their* Contact Effects.

By THOMAS H. HOLLAND, A.R.C.S., F.G.S., *Deputy Superintendent, Geological Survey of India*, and WALTER SAISE, A.R.S.M., D.Sc., F.G.S., *Manager, East Indian Railway Company's Collieries, Giridih.* (With map., pl. 4, and two wood-cuts.)

CONTENTS.

I.—INTRODUCTION.

1. The dyke-rocks of the Giridih coalfield have been mentioned and mapped by Mr. T. W. H. Hughes, late Superintendent, Geological Survey of India, in a memoir published in 1868[1]. The 15 dykes described by that author were classified as (1) dioritic traps, (2) compact felspathic traps, and (3) micaceous traps. Mr. Hughes

[1] *Mem. Geol. Surv. Ind.*, Vol. VII, p. 209.

has also briefly referred to the crystalline rocks which fringe the whole coalfield and form also two faulted inliers amongst the Talchirs in the north-west corner.

2. Later investigations facilitated by widely-extended subsequent mining operations have enabled us to add many facts concerning the relations and field characters of these dykes, whilst microscopic and chemical examination in the laboratory of the large number of specimens collected has revealed many additional facts, which appear to be of both local and general interest. We gratefully acknowledge the help most generously given in many ways by Mr. T. H. Ward, F.G.S.

II.—GENERAL STRATIGRAPHICAL CHARACTERS OF THE COALFIELD.

3. The Giridih (Kurhurbaree) coalfield consists of a small patch of strata of Barakar and Talchir age, measuring 11 square miles, and preserved between three nearly parallel faults, which trend east and west. The Barakars appear at the surface for over 7 square miles and the Talchirs for over 3⅛ square miles, the remainder ⅞ square miles, being inliers of crystalline rocks.

Barakar Stage.

4. The Barakars, having a total thickness of nearly 1,000 feet, include at the top several great seams of inferior coal (the *hill seams*) with coarse sandstones, conglomerates and dark felspathic grits, lying on 500 feet of light-grey, coarse sandstones and conglomerates containing well-rounded boulders of quartzite, with dark grey grits, and a few bands of shale or impure coal. Underneath these beds occur 150 feet of grits in which the two main seams of Kurhurbaree coal occur (Kurhurbaree upper and lower seams).

Talchir Stage.

5. The Talchirs, lying below the Barakars, consist of friable, greenish and yellowish sandstones overlying yellow and blue shales, which weather in a very characteristic fashion into nodular masses and acicular fragments. Underneath these shales occurs the well-known boulder-bed. The total thickness of the Talchirs is about 150 feet.[2]

III.—THE IGNEOUS ROCKS.

6. According to their geological age, the igneous rocks may be grouped into—

(*a*) those which were intruded into the crystalline series before the deposition of the Talchir group, and

(*b*) those which have been intruded subsequent to that period, and, probably, subsequent to the formation of the youngest Damuda rocks in Bengal.

7. The time which elapsed, therefore, between these two sets of intrusions was at least as great as that required for the deposition of the Damuda series. We shall give below (paras. 17,18 and 30) the evidences which suggest that some of the former group of intrusive rocks (*Pre-Damuda*) were subjected to statical metamorphism

[2] Detailed descriptions of the stratigraphy of this area will be found in the memoirs by Mr. Hughes (*Mem. Geol. Surv. Ind.*, Vol. VII (1868), p. 209), and in a paper recently published by one of us (Saise, *Rec. Geol. Surv. Ind.*, Vol. XXVII (1894), p. 86). Reference to previous literature on the same subject will be found in these papers.

at the time of the intrusion of the oldest of the latter group (*Post-Damuda*), and subsequently suffered from the results of dynamical metamorphism, probably when the main faults of the field were developed.

(*a*) PRE-DAMUDA IGNEOUS ROCKS.

8. The crystalline rocks, which have already been mentioned, have been invaded by igneous rocks whose pre-Damuda age is assumed principally from negative evidence. They can be traced up to the boundary faults in several places, but are never found within the limits of the stratified area; they are assumed, therefore, to be older than the boundary faults, and, with less certainty, than the Damuda strata forming the coalfield. The dyke of eurite on the north of the field marks the boundary for a considerable distance, the plane of the dyke-face forming apparently a line of low resistance along which the fault has developed.

9. Neglecting the question of the origin of the ordinary crystalline gneisses and schists, the rocks which form well-defined dykes and are considered to be of immediate igneous origin are—

(1) Diorites.

(2) Granites and Eurites.

(1) DIORITES.

10. By their resistance to the weather, the diorites generally rise as small hills from amongst the crystalline series. Similar rocks, in which, in hand-specimen, hornblende is always a prominent constituent, occur as dykes in various places amongst the crystallines of Chota Nagpore, the Sonthal Pergunnahs and Raniganj, but never breaking through the sedimentary rocks.

Origin of the diorites.

11. The way in which these have developed from an original pyroxene-plagioclase rock is very easily demonstrated in almost every one of these masses; but the secondary changes which have been brought about by both statical and dynamical metamorphism show some interesting variations in the different localities. On the north and east of the coalfield, for instance, the development of hornblende from the original pyroxene, and of a granulitic structure from an original granitic one, is accompanied by the production of large quantities of scapolite. In these rocks a prominent constituent is apatite. On the south of the coalfield, on the other hand, the augitic rocks pass into hornblende-granulites and even hornblende-schists, which are entirely devoid of scapolite. It is very interesting to note that in these rocks, which do not give rise to scapolite, there is, unlike those of the northern margin, not a trace of apatite.

Werneritization.

12. In the rock described in 1875 by Brögger and Reusch[3] as *gefleckter Gabbro*, and in which the apatite veins of Oedegaarden occur, Professor Judd has traced the changes by which plagioclase-felspar has been transformed into scapolite. Liquids under pressure and containing chlorine in some form or other produced

[3] *Zeitschr, d. d. geol. Ges.*, Vol. XXVII, p. 646.

cavities by solution along the twin-planes in the felspar, and these cavities became filled with supersaturated solutions of sodium-chloride. Following these changes, which form a part of the statical metamorphism[4] to which the rock has been subjected, crushing of the mass has produced a granulitic structure accompanied by the conversion of the mixture of plagioclase and sodic chloride into crystals of scapolite[5]. In the hornblendic rocks on the north-east boundary of the Giridih coalfield, in the neighbourhood of Paharidih and Mongrodih, we have a most striking illustration of the development of scapolite from plagioclase by the successive effects of statical and dynamical metamorphism similar to those which have been so beautifully traced in the celebrated *Apatitbringer* of Oedegaarden in Norway by Professor Judd.

Mineral composition of original rock.

13. The original rock contained both monoclinic and rhombic pyroxenes. The former appears under the microscope as colourless plates with a feeble attempt at an ophitic arrangement around the felspars. These are invariably changed at their margins into granules of hornblende. The rhombic pyroxene occurs in minute granular aggregates darkened by the products of schillerization and forming at the junctions with felspar reactionary fringes which are composed of radially arranged blebs of a colourless mineral and hornblende.

Statical metamorphism of the plagioclase.

14. The plagioclase felspars are invariably crowded with minute colourless liquid inclusions arranged along the twin-planes (see plate fig. 3). As the crushed rock gave, with nitric acid and silver nitrate, unmistakeable reactions for a chloride, we concluded that these inclusions, like those in the Oedegaarden rock, are solutions of sodic chloride.

Accessory constituents.

15. Amongst the accessory constituents, crystals of black iron ores, garnet which is of secondary origin, apatite, quartz and calcite are found in small quantities.

Dynamical metamorphism of the rock.

16. This compact rock with *granitic* structure, composed almost wholly of *pyroxene* and *plagioclase*, and in which the effects of statical metamorphism are so strikingly shown, passes within a short distance along the same dyke into a distinctly foliated *granulitic* rock, in which *hornblende* and *scapolite*, by far the most abundant constituents, are mixed with a granulitic aggregate of *clear* felspar and quartz. Not the least interesting features in the rock are the patches which have escaped the effects of the dynamo-metamorphism. In these the old granitic structure is preserved and the felspars still clouded with inclusions, whilst scapolite is absent.

Paragenesis of apatite and scapolite.

17. The frequent close association of apatite and scapolite in Norway, Canada and elsewhere, naturally reminds us of the remarkable apatite-bearing peridotite which breaks through the Damuda strata in the immediate neighbourhood of the scapolite-bearing rocks of this area. According to the analyses of Waage, quoted by Brögger and Reusch[6], the apatite of Oedegaarden contains from 3 to 5·8 per cent. of chlorine. In the Giridih area also the apatite of the peridotite is a chlor-apatite. We have

[4] On statical and dynamical metamorphism: *Geol. Mag.*, Dec. III, Vol. VI (1889), p. 243.
[5] *Min Mag.*, Vol. VIII (1889), p. 186.
[6] *Loc. cit.*, p. 674.

thus a suggestion for the origin of the chlorine, which has in both cases brought about the preliminary changes necessary for the formation of scapolite from plagioclase in a previously-formed pyroxene-felspar rock, such as that at Mongrodih and the *geflecter Gabbro* of Oedegaarden.

Geological age of the scapolite.

18. Accepting this explanation, the formation of the scapolite may have commenced at any time after the deposition of the Damuda rocks, which we shall show to be the oldest limit of the peridotite intrusion (see para. 29—32; also Holland, *Rec. Geol. Surv. Ind.*, vol. XXVII (1894), p. 132). For the subsequent movements of the rocks which gave rise to the granulitic and foliated structures, the Rajmahal eruptions which fissured the country in all directions must have been sufficient to account for the younger faults and the small amount of crushing which has produced a rough foliation approximately parallel to the main faults. We consider that the intrusion of the peridotite, the production of the leading faults, and the werneritization of the pyroxene-felspar rocks occurred in close succession, at a period not far removed from the time of the deposition of the Panchet rocks.

Uralitization.

19. The production of hornblende by paramorphism of the augite is the most conspicuous amongst the secondary changes which have been produced in the pre-Damuda pyroxene-plagioclase intrusions. There are two principal types of this change: (1) At Bonkhoonju, a small peak west of the Oosri nuddi and north of the coalfield, hornblende develops with crystallographic parallelism to the porphyritic augite from which it is derived, and the rocks have suffered comparatively little from crushing. (2) In Chepo hill and near Gujiadih, on the southern border of the coalfield, where the band of dioritic rocks runs east-north-east and west-south-west, parallel to the general strike of foliation in the crystalline series, the hornblende has formed in isolated crystals in the augite without definite crystallographic relations to the latter, whilst the rocks themselves are sometimes so crushed and foliated that they become fissile hornblende-schists.

Uralitization at Bonkhoonju.

20. (1) In the rocks from Bonkhoonju hill the large phenocrysts of augite are darkened with schillerization plates, and the change to hornblende takes place along the margins of the crystals, extending inwards to varying degrees. The hornblende selvages so formed show optical continuity over considerable areas, the vertical crystallographic axis of the mineral generally coinciding with that of the augite undergoing the paramorphic change.

Without scapolite.

There are again two types of these rocks. In one lot the large augites show a lustre-mottling in the hand-specimen, whilst the felspars retain their original long prismatic shapes, and are darkened by inclusions. In this type there are patches of biotite generally with a lump of black iron-ore in the centre of each patch, and a granular pleochroic rhombic pyroxene which occurs in conspicuous quantities. In the other type, the felspars show a granulitic structure, with either clear scapolite crystals or patches of a grey fibrous material which strongly resemble the decomposition-products of scapolite. Biotite occurs irregularly but always intimately associated with the hornblende from which it has possibly been derived. Sphene and apatite are scattered irregularly through all these rocks.

With scapolite.

Uralitization at Chepo and Gujiadih.

21. (2) The Chepo hill mass shows generally a more advanced stage in the uralitization to hornblende, the crystals springing up at irregular intervals in the augite crystals, and showing little regard for the optical orientation of their neighbours. Epidorites and even well-foliated hornblende-schists occur along the same band of rocks at Gujiadih. Sphene and colourless epidote are represented, but apatite (unlike the Bonkhoonju rocks) is noticeably absent; the acicular crystals scattered through the felspar shew a much higher double refraction than that of apatite.

(2) EURITES.

22. Besides the masses of binary granite which occur at several places amongst the felspathic gneisses, there are two large dykes of eurite—one running close to the northern boundary fault, and for some distance along the fault (see para. 8), and the other running in a parallel direction on the southern boundary from a point a little to the south of the junction of the Komaljore and Suni nadis to a point where the latter crosses the fault.

Structure of the eurites.

23. The eurite is a dark-green compact rock exhibiting a fracture which is conchoidal, except where interrupted by the numerous inclusions of hornblende-granite. Quartz in small granules is scattered through the grey microcrystalline matrix, and sometimes occurs in larger fragments which show crystal outlines. The absence of ferro-magnesian silicates amongst the phenocrysts is a very noticeable feature. The patches of coarse-grained granitic material, giving a glomero-porphyritic structure to the rock, contain considerable proportions of plagioclase with small quantities of hornblende. The whole rock has been brecciated and the pieces re-cemented with granular quartz.

(*b*) POST-DAMUDA INTRUSIONS.

24. The dykes which break through the stratified rocks of Damuda age are of two very distinct types:—

(1) A group of mica-peridotites remarkable for the amount of apatite they contain, and,

(2) Large dykes of basalt, younger than the foregoing set and probably the underground representatives of the Rajmahal lava-flows.

Dykes of the former class can generally be identified with the compact felspathic and micaceous traps of Mr. Hughes, whilst the latter are referred to as dioritic traps by the same author.

(1) PERIDOTITES.

Characters of Peridotite intrusions.

25. The rocks which have been generally known to previous wrtiers as "mica traps" occur in this and in most of the Bengal coalfields in the form of dykes and intrusive sheets with very marked characteristics. The dykes are generally narrow (3—5 feet)

and at the surface are always decomposed to a soft buff-coloured crumbling earth, which is often vesicular and contains remnants of partially-decomposed bundles of mica. Traced below the surface in the colliery workings, these dykes are seen to send out ramifying apophyses into the surrounding coal and sandstones, and in some places they thicken out into boss-like masses, or even spread out in wide sheets along the bedding planes, coking the coal with the production of beautiful columnar structures, baking the shales, and partially fusing the felspathic sandstones into compact rocks, which sometimes show structures in section like those seen in rhyolites (para. 53).

26. As compared with other igneous intrusions of this area, the results of the widely-extended results of contact-metamorphism produced by the irruption of these "mica traps" everywhere appear to a very marked degree. Taking this fact into consideration with the length of such narrow dykes in the different coal-fields, it seems natural to suppose, as previously suggested by one of us,[7] that the igneous material was injected in a very mobile condition at an exceptionally high temperature.

Microscopic characters of the Peridotites.

27. The colliery workings, besides enabling us to trace the various ramifications of these intrusive rocks, have exposed at greater depths masses of the rock which have suffered very little from secondary decomposition. The microscopic characters, which have been described in detail by one of us,[8] prove it to be of a type quite unique amongst the remarkable group of peridotites. A character which seems to be constant throughout the coalfield is the most exceptional quantity of apatite amongst the constituents of this peridotite, amounting in the freshest specimens obtained to as much as 11·5 per cent. of the rock. In these specimens which were obtained from the boss-like expansion in No. 7 Jogitand shaft, the apatite is accompanied by biotite, olivine, magnetite, chromite and a grey base which is considered to be the vitreous residue of the rapidly cooled and imperfectly crystallized magma. In other places augite and anthophyllite are amongst the ferro-magnesian constituents. Whilst the corresponding rocks in the Darjeeling coal-measures, where, by the way, apatite is subordinate in quantity, are sometimes composed entirely of crystals, those of the Giridih coalfield are, so far as our researches show, always hemicrystalline like the kimberlites described by Carvill Lewis in the Gondwana rocks of South Africa. As might be expected, the central portions of the larger masses are always coarser in grain than the more rapidly cooled selvages.

Decomposition of the Peridotites.

28. Subterranean circulating waters, in which the proportions of carbonic and to a less extent sulphuric acids are increased by the slow oxidation of the pyritous coal, bring about secondary changes in the rock constituents with the production of serpentine, followed invariably by rhombohedral carbonates and sometimes by secondary quartz. At the surface, oxidation of the iron compounds and removal of the alkalies and alkaline earths in solution leave a buff-coloured or rusty soft clay in which mica seems about the last mineral to lose its original characters.

[7] Holland. *Rec. Geol. Surv. Ind.*, Vol. XXVII, p. 133.
[8] Holland. *Loc. cit.*, p. 129.

Distribution and Geological age of the Peridotites.

29. Dykes of the mica-peridotite are found cutting through the hill seams and the Kurhurbaree upper seam; but it is in the lower seam that the intrusions are most numerous, and here they spread out in great sheets destroying the coal over large areas. As might be expected the greater pressure at lower depths forced the molten material along the bedding planes of the least resisting rock, namely, the coal.

30. On the accompanying map we have indicated the position of 19 peridotite dykes so far as they are traceable at the surface. These show a general tendency to run east and west. Whilst they cross the older faults in the lower seam they do not break through the boundary faults, as is the case with the younger basaltic intrusion. The intrusions are therefore younger than some of the faults *within* the coalfield but are probably older than the *boundary faults* of the field. This agrees with a suggestion we have already made that the statical metamorphism of the pre-damuda pyroxene-felspar rock of the adjoining area occurred at the time of the intrusion of this chlor-apatite bearing peridotite and the subsequent movements which changed the former rock into a hornblende-scapolite granulite brought about the great faults, which dropped the Giridih coalfield into its present position. It is certainly very significant to note with reference to this suggestion that where the original pyroxene-felspar rock was furthest removed from these peridotite intrusions, as at Chepo, there is not the slightest sign of scapolite in the foliated hornblendic rocks.

31. One of the dykes only (the Buriadih dyke, No. 2 on list) passes into the crystallines; and the boundary of the coalfield at this point is a natural one, not faulted.

32. The highest strata amongst the Damudas at Giridih are cut by the peridotite dykes. Passing to the Raniganj coalfield we find the youngest Damuda beds there, namely, the Raniganj-stage, are also invaded by this rock; but beyond this we have no reliable evidence for fixing with greater precision the *oldest* limit of the intrusion. The *youngest* limit is determined by the basalts which, following Dr. Blanford, we regard as Rajmahal in age. We have thus a peridotite intrusion probably contemporaneous with the formation of some part of the Panchet group.

33. *Catalogue of the Mica-peridotite dykes in the coalfield.*

No.	Name of dyke.	Direction.	Thickness.	Remarks.
1	Dandidih . . .	NW—SE	3 feet	
2	Buriadih . . .	NW—SE	1 foot	No. 6 of Hughes.
3	Chunka . . .	NW—SE	2 feet	
4	Khandiha . . .	NNW—SSE	2 "	No. 8 of Hughes.

No.	Name of dyke.	Direction.	Thickness.	REMARKS.
5	Kopa	NNW—SSE	2 "	No. 15 of Hughes.
6	Baniadih	NW—SE	1 foot	
7	Bungalow pit Buniadih .	W—E	1½ "	No. 10 of Hughes.
8	Domahani . . .	W—E	1 "	" 11 " "
9	Jubilee pit . . .	W—E	6 inches	" 10 " "
10	Bhaddoah hill . .	W—E	1 foot	
11	Sariabad . . .	W—E	1 "	
12	Gapae	WSW—ENE	1 "	
13	Satighat . . .	NW—SE	1 "	No. 13 of Hughes.
14	Bittagarha . . .	ENE—WSW	1 "	
15	Jogitand . . .	ENE—WSW	1 "	
16	Jogitand—Lunki . .	WNW—ESE	1—5 feet	No. 5 of Hughes.
17	Chaitadih . . .	WNW—ESE	1 foot	
18	Mowlichooah . .	N—S	2 feet	No. 1 of Hughes.
19	Birwadih . . .	W—E	1 foot	

(2) BASALTS.

34. The greater thickness and the spheroidal weathering of the hard, black or dark-grey basalts are characters which serve to distinguish without difficulty the dykes of this rock from those of the mica-peridotite with which, within the limits of the coalfield, they are so frequently associated. These dykes sometimes attain a thickness of 100 feet, and yet nowhere has the action of this rock on the strata produced results in any way comparable to the effects of the much narrower intrusions of the mica-periodotite. So far as we know, the basalts never spread as sheets along the bedding planes of the sedimentary strata which have been invaded.

35. Specimens of the basaltic rocks have an average specific gravity of 2·99. Under the microscope they are seen to be composed of *olivine*, partially decomposed with the formation of green and yellow serpentine, *plagioclase felspar* in lath-shaped crystals, *magnetite*, often developed around the felspars, and included by the pale brown *augite*, which is developed ophitically around the crystals of earlier consolidation. There is always a residue of feathery microlites in a hyalopilitic matrix.

Occurrence and geological age of the basalts.

36. The basalts cut through the faults within the limits of the coalfield and strike across the boundary faults into the adjoining crystalline series. Where their junctions with the peridotites have been exposed and examined, it is seen that the

latter rocks are displaced and cut through, proving the basalt to be distinctly younger than the mica-peridotites. (See fig. 1). Seeing they cut across the boundary faults, they may be regarded as younger than the coalfield as a whole.

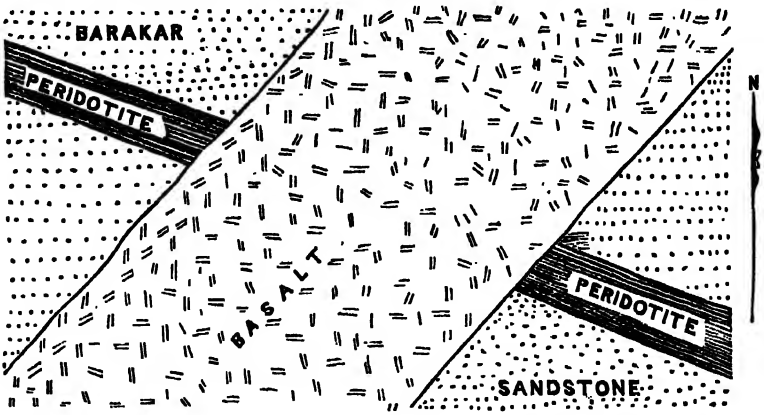

Fig. 1. Plan showing the Baniadih-Komaljore dyke of basalt crossing the Jogitand-Lunki dyke of peridotite.

Following the conclusions of Dr. Blanford concerning the age of the augitic dykes of the Raniganj coalfield[9] and of subsequent workers in other Bengal coalfields, it seems safe from analogy to consider these basalts to be the dyke representatives of the petrologically similar basaltic outflows of Rajmahal age.

37. The following is a list of the six basaltic dykes mapped:—

No.	Name of Dyke.	General direction.	Thickness.	Remarks.
1	Pandadih . . .	E—W	20 feet	In the crystallines.
2	Maniktand . .	NW—SE	50 ,,	No. 14 of Hughes.
3	Dhobidih-Mowatand .	NW—SE	5—100 ,,	,, 12 ,, ,,
4	Baniadih-Komaljore .	NE—SW	5—100 ,,	No. 9 ,, ,,
5	Baniadih . . .	NW—SE	30 ,,	......
	Kopa-Kabribad .	E—W ESE—WNW	5 - 50 ,,	No. 7 of Hughes.

38. The two sets of intrusive rocks just considered—the mica-peridotites and the basalts—are associated with one another in nearly all the coalfields of Bengal, and we have shown that the more basic eruption has been the first to be intruded. As all workers agree in considering the basalts to be of Rajmahal age, and we have shown that the peridotites are younger than the Raniganj stage, these two sets of intrusions cannot differ very greatly in geological age. But they are nevertheless quite distinct in order of eruption. They are equally distinct in petrological

[9] *Mem. Geol. Surv. Ind.*, Vol. III, pp. 141–149.

characters and mode of occurrence; and we do not see that there is any proof of their having been derived from a common magma, although this has been assumed so frequently during the last two or three years as a necessary premise for explaining the irruption in order of basicity of igneous rocks associated with one another within the limits of comparatively small areas. The older set of intrusions are represented by mica-peridotite as the leading petrological type; they occur in all the coalfields of Bengal from Raniganj to Darjeeling, and are of about Panchet age. In places by the introduction of felspar, these pass into basalts, but of a type which could never be mistaken for the Rajmahal rocks. The younger group of intrusions are basalts with olivine passing into augite-plagioclase rocks; they stretch to considerable distances around Raniganj, and belong to a petrographical province of Rajmahal age. It would be a great convenience if we had some conveniently short nomenclature to express the geological age, geographical limits, and petrological facies of petrographical provinces so marked as these cases presented to us in Bengal.

Relations of the peridotites and basalts.

(3) COMPARISON WITH SOUTH AFRICAN INTRUSIONS.

39. In studying the post-Damuda intrusive rocks of this and the other coalfields of Bengal, it is impossible to overlook the apparent parallelism with the igneous rocks which invade the Karoo system of South Africa. Although the South African beds have not been sufficiently investigated to allow of great precision in correlating the various groups there represented with the Gondwanas of India, the palæontological and lithological characters of the deposits leave no doubt about the Karoo system being homotaxially equivalent to the lower and a portion of the upper Gondwana system in India.

40. The rocks intrusive into the Karoo beds belong to two groups:—

(1) The diamond-bearing peridotite breaking through the Ecca beds and Kimberley shales.

(2) The basaltic rocks which break through the whole series and form contemporaneous lava-flows capping the Stormberg beds.

41. In India we know beyond question that the peridotites are older than the associated basalts. In Africa we only know that they break through the older strata and are not found in the higher beds.

42. In India the basaltic dykes break through the whole of the lower Gondwanas and are considered to be the underground representatives of the Rajmahal lava-flows. The basalts of South Africa traverse in like manner the complete Karoo system from the Ecca stage to the Stormberg beds.[10] Whilst it is not yet possible to fix exactly the position, and especially the youngest limit, of the Stormberg beds, they are certainly not older than the Panchets and are probably not far removed in age from the Rajmahals.

43. Whilst admitting, therefore, that the evidence is but fragmentary, we consider that the facts of stratigraphical distribution and petrological features, so far as they are known, are sufficient to warrant as a tentative conclusion the existence of one, if not two, petrographical provinces of Gondwana age extending from South

[10] Green *Quart. Journ. Geol. Soc.*, Vol. XLIV, (1888), p. 239.

Africa to India. The oldest of these was characterised by peridotites, and these were followed, at a period not far removed, by enormous outflows of basalts and augite-andesites.

IV.—CONTACT-EFFECTS.

44. The intrusions of peridotites and basalts into the Damuda strata have given rise, as already stated, to very marked contact-metamorphism, especially in conjunction with the former group of igneous rocks. The results, as might be expected, are most striking amongst the coals, whilst the sandstones have been hardened by baking and even partial fusion, and the shales merely baked.

1. Contact-Metamorphism of the Coal.

45. Even the narrow dykes of peridotite, where they pass through the coal seams, are bordered with a zone of beautifully columnar coke two or three feet thick on either side of the dyke. The volatile bituminous matter having been driven off, the resulting contraction in the mass produced a columnar structure with injections of thin films of the igneous rock along the cracks.

46. The series of proximate assays given below are of altered coal taken at gradually increasing distances from the margin of the peridotite dyke, and compared in each case with specimens of unaltered coal from the same seam.

Series A.

47. Specimens taken from lower seam, south of No. 7 Jogitand s[illegible], Giridih coalfield:—

Thickness of peridotite dyke, 4 feet.
Thickness of coked zone, 3 feet 6 inches.

	Numbered from the Dyke outwards.					
	1	2	3	4	5	6
Volatile matter (excluding moisture.)	4·10	4·89	6·40	6·80	15·45	20·71
Fixed carbon . .	64·63	74·36	71·79	80·69	74·31	67·46
Ash	31·27	20·75	21·81	12·51	10·24	11·83
Total .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Does not cake. Ash, light brown.	Does not cake. Ash, light reddish brown.	Cakes, but not strongly. Ash, light reddish brown.	Cakes strongly. Ash, light brown.

Series B.

48. Specimens taken from lower seam on northern side of No. 7 Jogitand shaft, Giridih coalfield:—

Thickness of peridotite dyke, 3 feet.

Thickness of zone of altered coal, 3 feet.

	NUMBERED FROM THE DYKE OUTWARDS.					
	1	2	3	4	5	6
Volatile matter (excluding moisture).	5·31	4·95	6·71	4·84	8·01	19·10
Fixed carbon . .	71·51	72·84	77·70	83·29	78·72	59·43
Ash	23·18	22·21	15·59	11·87	13·27	21·47
TOTAL .	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Does not cake.	Cakes, but not strongly.

49. An examination of these assays leads to the following general conclusions:—

(1) There is a loss of bituminous matter as the igneous rock is approached.

(2) The fixed carbon at first increases in proportion to the loss of the volatile constituents until close to the dyke the fixed carbon again decreases, which we presume to be due to its oxidation and replacement by inorganic bases.

(3) The ash increases in percentage as the dyke is approached, and this increase is far greater than would be due to the simple removal of volatile matters (*vide infra*, para. 52).

50. These conclusions are more uniformly illustrated by considering the averages of assays of adjacent pairs of samples and compared as follows with a sample of unaltered coal from the same seam:—

Series A.

NUMBERED FROM THE DYKE OUTWARDS.

	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . .	4·49	6·60	18·08	22·12	24·70
Fixed carbon . . .	69·50	76·24	70·89	66·60	65·99
Ash	26·01	17·16	11·03	11·28	9·31
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	Cake.	Cake strongly.	Cakes strongly.

Series B.

	1 and 2.	3 and 4.	5 and 6.	Two specimens at 4 feet from dyke.	Specimen at 10 feet from dyke.
Volatile matter . .	5·13	5·77	13·55	26·40	27·80
Fixed carbon . . .	72·18	80·50	69·08	66·65	66·16
Ash	22·69	13·73	17·37	6·95	6·04
	100·00	100·00	100·00	100·00	100·00
	Do not cake.	Do not cake.	No. 6 cakes slightly.	Cake strongly.	Cakes strongly.

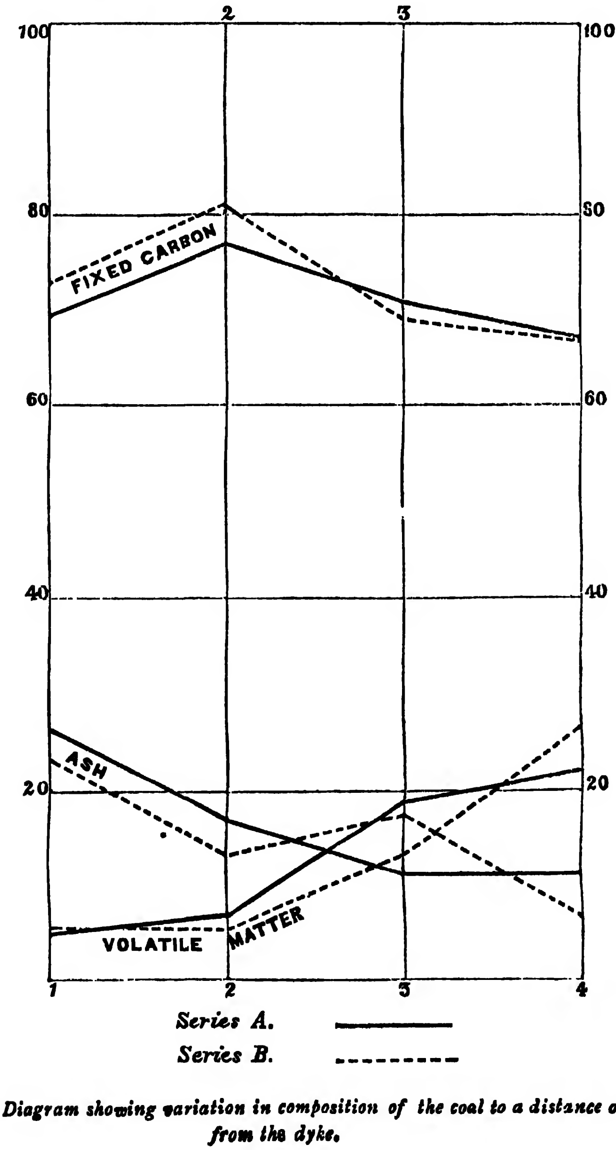

Fig. 2. Diagram showing variation in composition of the coal to a distance of 4 feet from the dyke.

51. The following assays of specimens kindly supplied by Mr. F. J. Agabeg from a coal seam invaded by peridotite in pit No. 2, Cheranpore colliery, Asansol, show a similar series of results :—

	No. 1. Average of 4 samples into which veins of trap have ramified near dyke.	No. 2. Average of 2 samples outside the former group.	No. 3. Unaltered coal from the same seam.
Volatile matter	6·44	11·55	31·40
Fixed carbon	49·37	69·86	58·65
Ash	44·19	18·59	9·95
	100·00	100·00	100·00

52. If the increase in the percentage of ash were due simply to proportionate removal of the volatile constituents, we should expect a maximum in each case as follows :—

Series A :— . . . . 13·7 per cent. Ash
,, B :— . . . . 8·8 ,, ,, ,,
Cheranpore :— . . . . . . 13·2 ,, ,, ,,

Whereas we have 31·27, 23·18 and 44·19 per. cent. respectively.

Increase of Ash percentage.

Sir I. Lowthian Bell in discussing the origin of the bases in the "white post" lying above the basalt in Durham colliery considers that bases are sublimated from the highly heated basalt at the time of its intrusion in the molten state.[11] Whilst this may have taken place in the case of our still more highly heated peridotites, we consider that in this particular case the largest portion of the inorganic material has been introduced subsequent to the consolidation of the igneous rock by infiltration of solutions into the coke which is naturally more vesicular where it has lost most of its bituminous matter. The peridotites are all highly decomposed in the small dykes and on the selvages of the larger masses, and the deposition of rhombohedral carbonates and quartz in place of the original olivines is sufficient evidence of the re-arrangement of bases which has been brought about in the rock by secondary causes since consolidation.

CONTACT-METAMORPHISM OF SANDSTONES.

Fusion of the Felspathic sandstones.

53. About the most remarkable amongst the effects of contact-metamorphism are the changes produced in the Barakar sandstones. Hardening of the sandstones is common enough wherever they come within range of the peridotite sheets, but in some places, where the sandstones are felspathic and with partially kaolinised felspars, there has been a partial fusion produced, with the result that the quartz and felspar crystals have been rounded and corroded in bays and inlets like the phenomena so common in the rhyolitic lavas. The glass formed by the fusion is crowded with radially arranged microlites, and generally so strikingly recalls the

[11] *Proc. Roy. Soc.*, Vol. XXIII (1875), p. 543.

appearance of a rhyolite that we found it necessary to reassure ourselves by repeated field examination that we had not by chance sampled a hitherto undetected acid lava-flow. There is no doubt, however, about the nature of the rock with which we are dealing. It can be traced out to sandstones which are merely baked or fritted and thence to the loose characteristic Barakar sandstones with decomposed felspars. The signs of fusion discovered by the microscope are after all only in agreement with other evidences which point to the very high temperature of the peridotite intrusion, and taking this fact in connection with the tendency of this peridotite to spread in sheets amongst the sedimentary rocks, we see an explanation for the beds of hardened sandstone which so puzzled earlier observers that they were often described by the vague term "trappoid sandstones" and have even been considered "traps" —a blunder the more easily made by the field-worker from the way in which these hardened sandstones form ridges running across the country and breaking with a cuboidal jointing so common in trap-flows.

54. It is interesting to note that Mr. Hughes also, as long ago as 1866, explained the occurrence of similar hardened ridges as the result of "trappean action" in the Jherriah coalfied, where they also show a columnar structure.[12]

We have figured and described a slide showing the results of the partial fusion of a sandstone which is associated with the peridotite plexus of Bhaddoah hill (plate I, fig. 6).

V.—SUMMARY OF RESULTS.

55. The igneous rocks of the Giridih area may be divided into two groups:—

1st.—*Eurites* and *pyroxene-plagioclase* rocks which were intruded amongst the crystalline rocks before the deposition of the strata of the Damuda epoch.

2nd.—*Mica-peridotites* and *basalts* which have invaded the Damuda series.

56. The pyroxene-plagioclase rocks have undergone two sets of changes. On the north of the coalfield they have passed into *uralite-diorites* and *epidiorites* with the formation of much *scapolite*. On the south they have changed into epidiorites, and hornblende-schists *without* the development of scapolite.

57. The *statical metamorphism* of the plagioclase in the plagioclase-augite rock probably took place at the time of the intrusion of the apatite-bearing mica peridotite, and the subsequent *dynamical metamorphism* attended with the development of scapolite was probably contemporary with the formation of the great boundary faults of the coalfield.

58. The *mica-peridotites* are remarkable for the large quantities of *apatite* they contain, sometimes amounting to over 11 per cent. These rocks are post-Damuda though pre-Rajmahal in age. They form long narrow dykes in the younger strata and spread out in wide sheets at greater depths.

59. The *basalts* occur in wider dykes breaking across the peridotites and are regarded as the underground representatives of the Rajmahal lava-flows.

60. There is a striking parallelism between the post-Damuda intrusions of Bengal aud those invading the Gondwana rocks of South Africa, where the diamond-bearing peridotite of Kimberley is succeeded by enormous outflows of basalt.

61. The effects of *contact metamorphism* of the mica-peridotite are far more

[12] *Mem. Geol. Surv. Ind.*, Vol. V, p. 323.

striking than those of the basalts, although the latter form very much thicker dykes. The former rock we conclude was introduced at a very much higher temperature.

62. Amongst the contact effects the partial fusion of the felspathic sandstone is a feature worthy of record. During the coking of the coals the loss of bituminous matter has been accompanied by a more than proportionate increase in the percentage of ash, the additional inorganic material having been introduced by infiltration into the vesicular coke of salts in solution subsequent to the consolidation of the igneous rock.

VI.—EXPLANATION OF MAP AND PLATE.

MAP.—The stratified rocks (Talchirs and Barakars) are confined to a basin-shaped depression of about 11 square miles with two inliers of crystalline rocks (shaded in pink) in the north-west corner. Outside the boundary of the sedimentary rocks, which are sometimes cut off by a fault and sometimes limited by a natural boundary, the country consists of various crystalline rocks, felspathic gneiss and mica-schists being specially common. Quartz veins and veins of coarse graphic granite frequently occur in these. The direction of foliation of the crystalline rocks varies within small limits, but generally conforms to the direction of the main faults which bound the coal-field on its northern and southern margins, besides dividing it in a parallel direction near the centre. The northern boundary fault coincides for some distance with a dyke of eurite, the face of which probably affords a plane of low resistance. The position of the diorites has been marked at Chepo Hill and Gujiadih on the south, at Bonkhoonju on the north, and at Paharidih, Birwadih and Mongrodih on the east. Wherever these rocks are foliated, the foliation is parallel to the general foliation of the crystalline series around, and, consequently, to the direction of the great faults of the field. The diorite forming the conical mass at Bonkhoonju is not foliated, but the gneisses dip on both sides towards the hill, forming a syncline whose axis runs about east-north-east and west-south-west (*vide* paragraphs 10—21). Catalogues of the peridotite and basalt dykes are given in the text (paragraphs 33 and 37). Their position and names are plainly indicated on the map. The positions of property boundaries (indicated by thin lines joining the pillars) are shown for the purpose of finding in the field any required outcrop, as some of the dykes are so small and decomposed that they are not often easily detected.

PLATE.—*A series of photographs of thin sections under the microscope.*

FIG. 1. *Pyroxene-plagioclase rock* from Mongrodih near Giridih. Magnified × 20 diameters. The white felspars in long flat crystals are surrounded, with an imperfect ophitic arrangement, by augite. Some of the pyroxene, probably rhombic in some cases, has formed very fine mesh-work fringes on changing to hornblende and by reaction with the adjoining felspars, which latter have consequently lost their sharp outlines. Opaque iron-ores often occur in the patches of granular hornblende and sometimes form the nucleus of a garnet

aggregate. The change to green hornblende has taken place along the margins of nearly all the pyroxenes, as shown by the large crystal on the left.

FIG. 2. *Epidiorite with scapolite.* Mongrodih, near Giridih. Magnified × 20 diameters. The rock consists of a granular aggregate of hornblende scapolite, felspar and quartz. The scapolite may be recognised amongst the colourless constituents by the slight streakiness produced by incipient decomposition. This rock occurs near the margins of the mass of which fig. 1 represents the centre. The rock represented by fig. 1 consists of pyroxene and plagioclase, the latter constituent containing a series of cavities infilled with sodic chloride solution. As the result of subsequent dynamical metamorphism, the ophitic intergrowths shown in fig. 1 have been destroyed, the augites changed into granular hornblende, and the mixture of plagioclase and sodic chloride converted into scapolite with a small residue of clear felspar and quartz.

FIGS. 3 & 4. Crystals of *plagioclase-felspar* from the pyroxene-plagioclase rock of Mongrodih. Magnified × 37 diameters. Fig. 3 under ordinary light shows the bands of secondary inclusions of sodic chloride, which, when viewed between crossed nicols (fig. 4), are seen to coincide with the planes of composition of the lamellar twins. The statical metamorphism has thus resulted in the solution of the felspars along the planes of composition, which are regarded by Professor Judd as planes of chemical instability. The felspars in this rock afford very striking illustrations of the production of this form of schillerization along the planes between the twin-lamellæ (*cf.* Judd *Min. Mag.*, Vol. VIII (1889), pp. 189, 197).

FIG. 5. *Epidiorite* approaching *hornblende-schist*, Gujiadih, south of the Giridih coal-field. Magnified × 20 diameters. This is one of the extreme results of the metamorphism of the pyroxene-diorites, which, near the southern margin of the coal-field, are changed into well foliated hornblendic and granulitic rocks *without* the development of the scapolite that so frequently characterises the corresponding types on the north and east.

FIG. 6. *Felspathic sandstone*, partially fused by an intrusion of peridotite. Bhaddoah hill, magnified × 20 diameters. The quartz crystals have been corroded into bays and channels by the fused hydrated silicates, and the cooling of the latter has given rise to radial arrangement of black microlites precisely similar to those in the imperfectly crystallized matrix of many rhyolites.

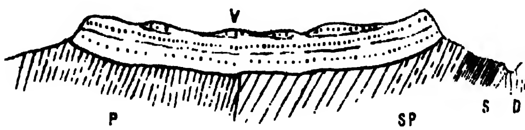

FIG. 1. SECTION THROUGH EAST END OF THE KHARÁRA OUTLIER.

Sb, Basal Beds. V, Vindhyan SP, Porcellanites of the Sub Kaimur series

P, Beds older than Sub-Kaimur.

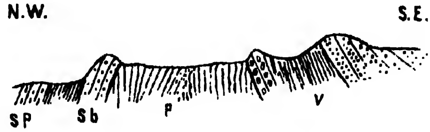

FIG. 2. SECTION NORTH WEST OF BARHATA.

Lettering as in fig. 1.

FIG. 3. SECTION AT RIGHT ANGLES TO 2

Scale of Sections 2 = 1 Mile.

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On some outliers *of the* Vindhyan system South *of the* Son and their relation *to the* so called lower *Vindhyans: by* R. D. OLDHAM, A.R.S.M., F.G.S., *Superintendent, Geological Survey of India* (with plate 5).

It has long been known that the Vindhyan system proper is underlaid, in Bundelkhand as in the Son valley, by a series of shales and limestones, regarded as conformable to the overlying system of sandstones, though their true relationship had not been fully cleared up. This series of shales and limestone was consequently accepted as a member of the Vindhyan system under the designation of lower Vindhyan.

The earliest published reference to these rocks is in a communication by the late Dr. T. Oldham to the Asiatic Society in 1856. In this the term Vindhyan was first proposed[1] for the system of sandstones and associated shales and limestones to which it is still applied. The beds below the Kaimur sandstone, which were subsequently accepted as lower Vindhyan, are there separated from the Vindhyans, under the name of 'Sub-Kymore,' a term proposed by Mr. H. B. Medlicott[2] to cover all the rocks below the Kaimur sandstone.

The next reference to these rocks is in Mr. Medlicott's memoir on Bundelkhand, where a very similar series of rocks is exposed in a corresponding position. The name 'Sub-Kymore' is abandoned and the series in question named Semri.[3] Reasons are given at one place[4] for considering the Semri beds as conformable with the Kaimur sandstone, but in other passages irregularities in the distribution of the upper groups of the Semri series are described, which do not seem compatible with complete conformity. Apart from this, the Kaimur conglomerate is said to contain pebbles of the chert-like shale of the lower Semri groups.[5] The observations recorded indicate a relation between the Kaimur sandstone and the underlying beds very similar to that which is found in the Son valley.

In the same volume the beds below the Kaimur sandstone in the Son valley are referred to by Mr. J. G. Medlicott under the name of Sub-Kymore;[6] no details are given, and, as in the original publication,[7] the term was evidently used to include rocks that are now separated as transition besides those which have come to be called lower Vindhyan.

This term was first publicly used in 1869 by Mr. F. R. Mallet in his account of the Vindhyan system[8], or series as it was then called; and in introducing the name it is said that recent investigations had established the identity of the Semri series of Bundelkhand and the Sub-Kaimur series of the Son valley, "at the same time establishing their close connection with the formation hitherto known as the Vindhyan. This connection, although close, is not sufficiently so to warrant our including both in one series. Hence the latter are now called *Upper Vindhyan*, the Semris and

[1] *Jour. As. Soc. Beng.*, XXV, 251 (1856).
[2] *Ibid*, p. 253.
[3] *Mem. Geol. Surv. Ind.*, II, p 6 (1860).
[4] *Ibid*, p. 13.
[5] *Ibid*, p. 28.
[6] *Mem. Geol. Surv. Ind.*, II, 138 (1860).
[7] *Jour. As. Soc. Beng.*, XXV, 253 (1856).
[8] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).

Sub-Kymores being distinguished as *Lower Vindhyan*."[9] In the descriptive portion of the memoir a closer connection is described than these words would suggest, facts and arguments being detailed which would indicate a complete conformity between the two series.[10] These are, firstly, the parallelism of dip observed along the boundary of the two series; and secondly, the absence of any signs of erosion on a contact section seen in the Dargaoti valley. At the same time other observations are recorded which are hardly compatible with complete conformity, but as it will be necessary to recur to this subject further on, its consideration will be deferred for the present.

In the first edition of the Manual of the Geology of India Mr. Medlicott's description of the Vindhyan series follows that of Mr. Mallet so far as the Son valley is concerned, and it is definitely stated[11] that the upper Vindhyans in this area conformably overlie the lower. This is to a slight degree qualified in another passage,[12] but the general impression left by the description is that there is no break of any importance between the two, and that the lower Vindhyans, so called, form part of the same great system of deposits as the upper.

When preparing the second edition of the Manual, I was struck by the indications of an unconformity, which are to be found in the original descriptions, and though the description of a region and system with which I had no personal acquaintance was left unchanged, except for some condensation, I felt it necessary to lay more stress on the possibility of an unconformable break between the two series and to question[13] the propriety of classing them together under one system.

Such was the state of our knowledge of these rocks till, during the last working season, upper Vindhyan outliers were found south of the Son, which have an important bearing on the relation of the so called lower Vindhyans with the Vindhyans proper. The subject is far from worked out and the region is still under survey, but some of the facts are clearly enough established to be worth publishing, in view of the interest attaching to this system.

The existence of Vindhyan outliers in the Son valley south of the boundary of the main area has long been known, and several are indicated on the map accompanying Mr. Mallet's memoir, but they had always been regarded as belonging to the so called lower Vindhyans.[14] During the past season several of these have been more or less completely examined, and it was found that they are of two distinct types and belong to two distinct series. We have firstly patches of unmistakable 'lower Vindhyan' rocks, highly disturbed and folded or faulted among the older transitions, and secondly outliers of much less disturbed and often nearly horizontal sandstones and conglomerates, which in one place were found to rest unconformably on the beds of the 'lower Vindhyans.' From their degree of induration these sandstones must be separated from the Gondwanas and, being younger than the 'lower Vindhyans,' may be referred to some horizon of the true or upper Vindhyans, which they resemble in lithological character and degree of induration.

[9] *Mem. Geol. Surv. Ind.*, VII, 27 (1869).
[10] *Ibid*, p. 46 ff.
[11] *Manual of the Geology of India*, 1st ed., 1879, I, p. 81.
[12] *Ibid*, p 90.
[13] *Manual*, 2nd ed., p. 98.
[14] *Mem. Geol. Surv. of Ind.*, VII, 45, *Manual*, 1st ed., p. 79.

We have accordingly south of the Son representatives of two series which to the north are apparently conformable, and as it will be inconvenient to call these by the same name, I propose, for the present, to resume the name of Sub-Kaimur for the 'lower Vindhyans.'

The only outlier which has been completely surveyed is that which lies west of the Samdin and south and east of the Son. Its position is indicated in the map accompanying Mr. Mallet's memoir, and it is at once the most westerly and the largest of those which must be ascribed to the newer series of rocks, or upper Vindhyans. Along its south-eastern margin a few small outlying patches of the same series are found, but to the north none exist between it and the Gidela outlier of the Kaimur scarp.

The outlier referred to is 12 miles long from east-north-east to west-south-west, of irregular shape, varying from half a mile to three miles in width, about the middle of which rises the Kharára G. T. S. Round the whole length of its boundary, except for a couple of miles where this is faulted, the outlier rests in obvious unconformity on the older underlying rocks. The rocks of which it is composed consist essentially of hard sandstones, white or red, many of which resemble the sandstones of the upper Vindhyans, more especially of the Kaimur group, though the series as a whole differs in the large number of pebbles it contains and in the frequent presence of a considerable proportion of felspathic material, whether as distinct grains of felspar or as a fine-grained felspathic paste. The pebbles are mostly of white vein quartz, generally small and ill rounded or angular, scattered through the sandstone matrix; at times however and in certain beds, which are not always at the bottom of the series, larger and better rounded pebbles are found in such abundance as to constitute a conglomerate. When this is the case a considerable proportion are found to consist of a bright red jasper, and the rock then resembles the descriptions of the Kaimur conglomerate.

Reserving more detailed description till a general account of the unsurveyed area in Rewah can be given, there are two sections which may be referred to here. The first of these is in the Samdin valley below Sejári village. Just below this village the Samdin flows over a barrier of vertically dipping quartzites of the Bijáwar type, the layers being separated by papery films of micaceous iron ore. Immediately north of this there is a thin layer of breccia, followed by conglomeratic sandstone, hardly visible in the stream bed, but easily seen a short way off on either side, followed by shales, by the porcellanic beds of the Sub-Kaimur series and by sandstones above these, the ascending section being cut off by a fault with an upthrow to the north. These Sub-Kaimur beds are at the western extremity of a long narrow outlier which has been traced, with a width dwindling from a mile and a quarter to nothing, for a distance of 25 miles to east-north-eastwards; the southern boundary being throughout natural and the northern faulted.

West of the Samdin the Sub-Kaimurs form the slope of a hill, capped by the eastern scarp of the Kharára outlier, the relations of the two series being indicated in the section No. 1 on the accompanying plate. This section is an absolutely decisive one, establishing beyond possibility of doubt that the sandstones and conglomerates of the outlier are distinct from those of the basal group of the Sub-Kairmur series to which they have been referred in previous publications.[15] The

[15] Memoirs, VII. 33.

observations of these outliers on which all previous accounts are based appear to have been made by Mr. Medlicott during a rapid march up the Son valley, the only record of which is contained in a manuscript report. Speaking of this Kharára outlier he says: 'On a first examination of this region from the north side, as actually occurred to me, one is disposed to look upon the rock of the high ridge as an overlapping remnant of an *upper* band of sandstone. For some time I entertained the conjecture that it might even be an upper Vindhyan rock.' This conjecture was abandoned for reasons which it is needless to detail here, and the sandstones of the outlier were ultimately accepted as identical with those of the basal group of the Sub-Kaimur series to the north, which, it must be acknowledged, they very closely resemble. Had Mr. Medlicott crossed the section in the Samdin, there can be no doubt that he would have adhered to his original conjecture, for here it is impossible to regard the two as identical. The Sub-Kaimur basal conglomerate and sandstone in the Samdin valley near Sejári is very much thinner than the same rock at the boundary of the main exposure, not five miles off; the thickness varies very much, but nowhere exceeds 100 feet, and the rock itself is a dirty sandstone containing small and scattered pebbles. The outcrop cannot be traced up the talus slope into actual contact with the outlier on the hill slope: it seems in fact to be cut off by a fault, but it is found within less than a quarter of a mile of the hard, clean, white, sandstones of the hill top, at whose base is a conglomerate containing numerous rounded boulders of quartz and scarlet jasper as large as a man's head, cemented by a clean silicious matrix. Even if these rocks did not rest unconformably on Sub-Kaimur beds, the great contrast in thickness and character of the two sandstones and conglomerates would leave no room for doubting their distinctness.

The other section to be considered is near the western end of the outlier and is interesting as showing the conditions under which the rocks composing the outlier were deposited. North-west of Barhata village the sandstones do not rest directly upon the older rocks, but are underlaid by a breccia composed of angular fragments of the underlying slates, a few inches in diameter, through which are scattered blocks of vein quartz running to as much as a foot in diameter. Towards its base this rock is almost devoid of fine grained matrix, but it passes by a gradual increase of sand and decrease of slate fragments into the overlying sandstone. The breccia, which is evidently an indurated fan deposit, attains a maximum thickness of over 700 feet, and is underlaid by a coarse conglomerate containing many ill-rounded pebbles of jasper, and numerous white quartz pebbles of six inches and more in diameter, besides darker and less conspicuous pebbles of quartzite, the whole being cemented by a matrix of dark red sandstone.

The section just described is figured in No. 2 of the plate, but these rocks below the sandstone do not continue along the outcrop to the east or to the west. The conglomerate is the first to disappear, its whole extent being less than quarter of a mile. The breccia extends further, but it too gradually thins out and disappears at three-quarters of a mile to the eastwards and half a mile to the west, as is indicated on the section No. 3, drawn at right angles to No. 2.

The explanation of these sections is evidently that the sandstones were deposited on a deeply eroded surface. At the bottom of the valley we have a coarse conglomerate deposited by a rapid torrent; this is succeeded by a fan deposit which gradually filled up the whole valley, and was itself covered up by the sandy deposits which obscured all the pre-existing irregularities of the surface, and converted what was once hill and valley into a broad sandy plain.

A similar lesson is taught by the Dádri outlier, about fifty miles east by north from the eastern extremity of that just described. West of it there runs in an east by north direction a ridge of vertical Bijáwar quartzites, which owes its prominence to the comparative softness of the rocks on either side. Just west of the boundary of the sandstone outlier this is breached by a cross valley, but is continued on the plateau as a low ridge, rising out of the sandstones on either side, which runs for a couple of miles before being finally covered up. Here it is evident that the older rocks had undergone practically all the disturbance they now exhibit before the still nearly horizontal sandstones had been deposited, and had, besides, been exposed to sub-aerial denudation for a period long enough to produce an uneven surface in which the harder beds were represented by elevations and the softer by depressions of the surface.

These remarks regarding the relation of the outliers to the older rocks apply to the Sub-Kaimurs almost as much as to the transition rocks, for the amount of disturbance they have undergone in their outliers is great, and they had shared in the same denudation to which the transition rocks were exposed. It would consequently be difficult to find a more decided unconformity than that between the sandstone outliers on the hill tops, and the Sub-Kaimur series in their proximity, and a question arises as to the age of the former. To this only one answer seems possible: they are certainly of later date than the Sub-Kaimur series, and it would be preposterous to suppose that these indurated and ancient looking sandstones could be the same as the soft sandstones of the Gondwana series. It would be almost equally absurd to suppose they form a separate series of deposits by themselves not referable to any other in the neighbourhood, and the only alternative is to regard them as outliers of the upper Vindhyans, for which they might easily pass. They cannot be identified with any specific horizon of that series, and though they resemble the Kaimur groups more than any of the upper sandstones, no importance need be attached to this, as the points of resemblance are probably the result of their being in either case the bottom beds of the series.

Accepting this identification, it would be natural to suppose that the facts given above would settle definitely the distinctness of the so called 'lower' from the 'upper' Vindhyans or Vindhyans proper. Such a conclusion must not however be too hastily adopted. In the second edition of the Manual of the Geology of India I have pointed out that the nature of the north-west boundary of the Vindhyans towards the Aravalli mountains presents some analogy with that of the tertiary and recent deposits of the Gangetic valley to the Himalayas, and suggested that the Vindhyans may have been formed during the compression and elevation of that range from its debris.[16] Now along the edge of the Himalayas we have instances of upper members of the tertiary series resting in unconformable contact on the upturned and denuded edges of the lower ones, while not far off may be found a continuous conformable section uniting the two. Similarly, it might be supposed that in the Son valley we had the upper members of the Vindhyan system overlapping on to the eroded edges of the lower beds, which had been involved in the mountain forming

[16] *Manual*, 2nd ed., p. 103.

processes going on along the margin of the basin of deposition, and this unconformity at the margin need not be incompatible with a complete conformity of the two further away from that margin.

There is, however, one flaw in the analogy, which appears to be a serious one. Along the southern margin of the Himalayas the general dip is northwards, and the outliers of the tertiary beds have for the most part a natural boundary to the south and a faulted boundary to the north, the upthrow being on the north, or mountain, side of the fault. In the Sub-Kaimur outliers the conditions are reversed, the natural boundary is to the south, the faulted are to the north, that is to say, both dip and upthrow are away from what should have been the mountain range and towards the basin of deposition. These facts point to the period of disturbance as having been altogether anterior to, and not contemporaneous with, the deposition of the upper Vindhyans; and if we add to this the indications that are to be found in the published description, and still more so in manuscript reports, of both overlap and transgression along the southern boundary of the main area of the Vindhyans, it is at any rate conceivable that there is a real unconformity there, in spite of the apparent conformity, on individual sections, which has been recorded.

The final settlement of this question must await a re-examination of the boundary of the Vindhyans proper, at present the case for the inclusion of the Sub-Kaimur series with them has been greatly weakened, and until we have more positive evidence of conformity along the main boundary of the two, it will be well to abandon the question begging name of 'lower Vindhyan' for the Sub-Kaimur series.

Notes on a portion *of the* Lower Vindhyan area *of the* Sone Valley, *by* P. N. DATTA, B. SC., F. G. S., *Geological Survey of India.*

Area defined.

The area, on the examination of which these notes are based, is that portion of the Rewah State in Central India which extends on the one hand from the Kaimur Range on the north to the Sone river on the south, and on the other from the stream by Hinaota, 12½ miles W. by S. of Ramnagar on the west to the neighbourhood of Churhat on the east.

The Lower Vindhyans of the Sone Valley as classified by Mr. Mallet.

The rocks of the Sone Valley designated 'Sub-Kaimur' by Mr. Medlicott and regarded as the equivalent of his 'Semri' system of the Bundelkhand area, have been described by Mr. F. R. Mallet as the Lower Vindhyans. In his memoir on these Lower Vindhyan rocks of the Sone Valley, Mr. Mallet arranges and classifies them into the following 'sub-divisions'[1]:—

(Descending order.)

11. Limestone.
10. Shales.
9. Limestone.
8. Shales, sandstone.
7. Limestone.

6. Shaly sandstone.
5. Porcellanic shales.
4. Trappoid beds.
3. Porcellanic shales.
2. Limestone.
1. Conglomerate and calcareous sandstone.

The classification of the Lower Vindhyans, as now proposed.

From the inconstancy of some members of the Lower Vindhyan rocks and the absence of such well-defined divisions as are noticeable in the Upper Vindhyans, the Lower Vindhyans have not been regarded as susceptible of arrangement into well-marked divisions like the Upper Vindhyans. From the detailed examination of the portion of the Lower Vindhyan ground under notice, however, it seems quite feasible to classify the rocks into the following well-marked divisions:—

(In descending order).

IV. Rhotas division.
III. Kheinjua division.
II. Porcellanic division.
I. Conglomeratic division.

Origin of the divisional names.

The term 'Rhotas' has been suggested from the ancient fort of Rhotasgurh[1], while 'Kheinjua'[2] has been proposed from the Kheinjua Hills which show these rocks. I propose the name 'Porcellanic' for the next underlying division of beds from the prevailing and well-marked porcellanic character of the rocks. From the absence, in this limited area, of a particular locality or land-mark where the beds which underlie the porcellanic division and form the base of the system, are well shown, I am at a difficulty to suggest at present a more suitable name than that of 'Conglomeratic' for these beds forming the bottom division of the system. We might name the division from the well-marked range which occurs between Saria and Bela, marking the edge of the basin and exhibiting well the bottom conglomerate and quartzite. But unfortunately the range is not named in the map at all. Hence the term 'Conglomeratic' has been chosen provisionally.

Thus we have the Lower Vindhyans classified into the following four divisions:—

IV. Rhotas	division,	including Nos.	11, 10 and 9[3]	of Mr.	Mallet's	'sub-divisions.'
III. Kheinjua	„	„	„ 8, 7 and 6[4]	„	„	„
II. Porcellanic	„	„	„ 5, 4 and 3[5]	„	„	„
I. Conglomeratic		„	„ 2 and 1[6]	„	„	„

Distinctive characters of the several divisions.

Distinctive characters of the different divisions.—While the Rhotas division is mostly calcareous—it is entirely so in the area under notice,—and the Kheinjuas are essentially argillaceous shales with sandstones, the peculiar feature of the beds

[1] Mem. G. S. I., Vol. VII, p. 28.
Manual, 1st Ed., Pt. I, p. 78.
„ 2nd Ed., p. 95.

[2] This term appears to have been first adopted on the field maps of Mr. W. L. Willson, late of the Geological Survey.

[3] Mem. G. S. I. VII, pp. 28, 42, 43.

[4] „ „ „ pp. 28, 38—41.

[5] „ „ „ pp. 28, 35—38.

[6] „ „ „ pp. 28, 31—35.

composing the Porcellanic division is indicated by the name itself. The bottom division is mainly arenaceous, the calcareous and argillaceous element being present only to a very subordinate extent.

IV.—RHOTAS DIVISION.

In the area under notice the shales No. 10 of Mallet's are nowhere developed.

Rhotas division.

Thus the division bed consists entirely of thin-bedded limestone. The bottom beds of the division exhibit a tendency towards concretionary character, well formed calcareous concretions being often developed.

Crystals of quartz have been found developed in the drusy cavities in the limestone in some places.

Much local puckering and crumpling is observable in these thin-bedded limestone beds, but the topmost beds—those by the junction with the Kaimur beds—show no evidence of disturbance.

III.—KHEINJUA DIVISION.

Kheinjua division. Sub-divided into 8 series.

The sub-divisions 8, 7 and 6 make up this division. But in the area under consideration it is divisible into the following well-marked series :—

(In descending order.)

i. *Argillaceous shales*, containing calcareous concretions with intercalated limestone beds. Arenaceous element almost absent.

ii. *Limestone band*—
Limestone pure ; no arenaceous or argillaceous element present.

iii. *Shales*—Arenaceous and argillaceous, with thin-bedded sandstone ; ripple-marked ; no calcareous beds.

iv. *Limestone with shales*—
Limestone very impure and ripple-marked ; shales reddish, sometimes calcareous, at other times not.

v. *Shales*—
Arenaceous and argillaceous ; much ripple-marked, and with quartzitic thin bands of sandstone.

vi. *Sandstone*—
Thick-bedded, compact and quartzitic.

vii. *Limestone with shales*—
Limestone purer than No. iv ; shales greenish and non calcareous.

viii. *Shales and sandstones*—
Sandstone generally thin-bedded ; shales greenish and laminated.

Persistence or otherwise of the several calcareous series in the division.

Of these series (i to viii) the limestone No. ii has been traced as far as Rampur, where it dies out. The series No. iv persists throughout the area, while the limestone vii is not traceable beyond "Ucheyra" of map, near Marjátpur; but a limestone appears again about this horizon at 2 miles S. E. by S. of Rampur (Lat. 24°19′ N., Long 81° 32′.5 E.) and continues eastwards, becoming concealed under the alluvium at the eastern extremity of the area.

II.—PORCELLANIC DIVISION.

This division is divisible into—

Divided into three sub-divisions.

Upper Porcellanic shales,	corresponding to	No.	5 of	Mallet.
Trappoid beds	"	"	4 "	"
Lower Porcellanic shales	"	"	3 "	"

Looked at broadly, the bulk of the division is composed of the fine-grained porcellanic shales, and in their midst, and rather nearer the base than the top, we find a band of coarser rocks to which the name "Trappoid" has been applied. The upper porcellanic shales have a considerable quantity of ordinary argillaceous shales, very little altered, intercalated in them. The "trappoids" are thoroughly well bedded, in beds often of the same thickness as the porcellanic shales They do not form a well definable band by themselves, but occur intercalated with the finer-grained porcellanics. The trappoids are generally of a bluish color, but vary in fineness of grain, some being like exceedingly fine-grained quartzites, while others are much more coarse and gritty, with the quartz grains generally rounded. Felspar is present, but is scarcer in certain parts than in others. No hornblende could, however, be detected in the area under notice.

I.—CONGLOMERATIC DIVISION.

COMPRISES { No. 2. Limestone.
No. 1. Conglomeratic and calcareous sandstone.

Further subdivision yet impracticable from want of good exposures in this area.

As no exposures were available in the area in question for a minute examination of the constituents of Mr. Mallet's 'subdivision' No. 1, *viz.*, the conglomeratic and calcareous sandstone, the 'subdivision' has been allowed for the present to stand as it was. The limestone, coming in just above the conglomeratic and calcareous sandstone, does not seem very prominent or remarkable in any way, but on the other hand seems to be of a very inconstant and variable character. So it seems preferable to take in the Limestone No. 2 with the 'Conglomeratic and calcareous sandstone' beds, and form the two into one division. It seems all the more reasonable to do so, as we find it stated that the lowest two 'subdivisions' (*viz.*, No. 2 Limestone and No. 1 conglomeratic and calcareous sandstone) appear to be in some measure equivalent to each other[7], a conclusion presumably based on an examination of the rocks over the whole area.

General composition of the conglomeratic division.

Although for want of suitable exposures in this area a proper subdivision of the division has not yet been possible, the following is the general composition of the division. The limestone (limestone "No. 2") passes into a dark bluish earthy rock, ferruginous in places; shale, sandstone with quartz and ferruginous bands and quartzitic sandstone, light to dark grey and fine-grained to coarsish, are next seen, while lower down, ferruginous calcareous beds with pale greenish shale passing down into a greenish argillaceous shaly sandstone come in close above the quartzite which forms the range between Bela and Saria. This quartzite, which is thick-bedded, compact and hard, and reddish to white in colour, has hardly any pebbles in its upper part, but becomes conglomeratic in the lower part, the pebbles being of white and reddish quartz, red jasper and quartzite.

Conformability of the several divisions of the Lower Vindhyans and relation to Upper Vindhyans.

All these divisions, IV to I, which make up the Lower Vindhyans, are conformable to one another. As to the relations of the Lower Vindhyans (1) to the rocks that underlie the system and (2) those that overlie the system :—

7 Manual, 2nd ed., p. 95.

(1) The lower junction of the bottom conglomerate (division I) of the Lower Vindhyans (or Semri) rests unconformably upon a gneiss in the area under examination.

(2) The upper junction of the Lower Vindhyans (that is, the Kaimur-Rhotas junction) has been stated to be unconformable on these grounds:—

(*a*) That the Kaimur beds overlap the Lower Vindhyans.

(*b*) The occurrence of Lower Vindhyan debris in the Kaimur beds 100 ft. or more from the base of the Upper Vindhyans[8]

(*c*) The existence of a sharp line of division between the Kaimur and the Rhotas, especially in the sudden and abrupt change from the fine-grained deposits of the Rhotas to the coarse sandstone of the Kaimur.[9]

Overlap does not necessarily prove unconformity.

With reference to the unconformity from overlap, it is apparent that overlap need not always imply unconformity. The existence of overlap would not by itself prove any unconformability if unsupported by other evidence.

Denudation unconformity.

As to erosion-unconformity. The occurrence of Lower Vindhyan debris 100 ft. or more above the base of the Kaimurs has found neither confirmation nor negation from my personal observations in this area. For, though in the course of my examination, I cannot say I could detect any such Lower Vindhyan debris in the Kaimur beds, it must be remembered that the slopes of the Kaimur scarp in the area in question are exceedingly unfavourable for close examination. The Kaimur conglomerate is absent in this area.

No Kaimur-Rhotas contact proving erosion could be detected here.

Whenever the state of exposure allowed an examination of the ground to be made, I never succeeded in coming upon a contact of the Rhotas limestone with the rocks above indicating erosion-unconformity. The shales[10] overlying the Rhotas limestone certainly seemed thicker in some places than in others, but whether this was due to the original variability in the thickness of the shaly deposit, or to denudation of the underlying limestone rock in places (where the accumulation of shales would thus be greater than elsewhere) before the deposition of the shales, or to local depression in the rim of the basin which would thus take out of sight some of the lower beds, it was difficult to make sure. Should there have been denudation in the case, the contact between the limestone below and the shales above ought to show evidence of erosion somewhere or other. But although I did not succeed in coming upon an exposure proving the denudation of the limestone before the deposition of the shales, this does not of course disprove its existence, having regard to the nature of the ground.

Disturbance of Rhotas limestone not anterior to deposition of the Kaimurs.

There is certainly much evidence of disturbance in the beds of the Rhotas limestone, often in close vicinity to the base of the Kaimurs which are, however, quite undisturbed. That the Rhotas limestone might have been disturbed and contorted before the deposition of the Kaimurs is contradicted by

[8] Mem. G. S. I, VII, pp. 47 and 50; Manual, 2nd ed., p. 99.
[9] Mem. G. S. I., VII, p. 47; Manual, 2nd ed., p. 99.
[10] These are the Bijaigarh shales in all probability.

the invariable complete parallelism of the topmost Rhotas limestone with the Kaimurs, which has been observed in this area wherever a clear point of junction has permitted an examination.

As to unconformity from abrupt change in lithological character.

With regard to the unconformity as inferable from sudden change in lithological character from the Rhotas into the Kaimur beds, the examination of this junction in the area under report has been found to be attended with circumstances of considerable disadvantage, for the débris from the steeper parts of the Kaimur scarp form in most places a talus along the lower slopes of the scarp, rendering it a most difficult task to come upon an exposure showing a clear point of junction of the Rhotas limestone with the Kaimur rocks. The following are some of the localities where the sections at or near the junction were found to be instructive.

Section at Gursari ghat.

Gursari ghat.—Here the siliceous shales[11] (the shales that overlie the Rhotas) are seen to pass normally into the Kaimur sandstone of the scarp. The junction of the shales with the Rhotas is, however, concealed here.

Section by Hinaota.

Scarp-slopes by Hinaota.—(Approximate position, Long. 81°19′E, Lat 24°18′N.). The exposure here too is not perfect, but the Rhotas limestone seems to pass into a fine-grained homogeneous shale which, when freshly broken or exposed, is green, but turns bluish chalky white on exposure to the air. Such a rock is what we should expect to meet with as a passage rock from a limestone. For a little space up the slopes, above the foregoing shale, the ground is covered, but the shales that are exposed a little higher up are somewhat siliceous, and these pass above into the thick-bedded sandstone of the Kaimur scarp.

Exposure by Daorahra.

Foot of scarp-slopes, N. W. Daorahra.—Near Boorgaona. The homogeneous shale referred to as being met with in the last mentioned locality is also exposed here. But neither the junction of the Rhotas limestone with this shale, nor the passage of this rock into the siliceous shales and sandstone above, is traceable here.

Section by Majgama.

Scarp-slopes N. W. of Majgama.—The foot of the spurs is occupied by the Rhotas limestone. A little way up (*i.e.*, after a short blank section) a finely laminated soft shale, white, grey to blackish is seen (the shale is occasionally blackish enough to look carbonaceous). These soft shales pass upwards into shales somewhat harder, the colour being yellowish to brownish-grey, with a faint approach to a porcellanic look.[12] Beyond this point a talus of sandstone obscures the section, but the thick-bedded sandstone of the scarp is close above.

Section at Reiwas Hill.

Reiwas Hill.—(4½ miles N. by E. of Rampur, Lat. 24°24′·5 N, Long. 81°33′ E.) At the S. E. extremity of this hill, although the exact point of junction (Kaimur-Rhotas) is not to be seen, the uppermost Rhotas limestone as well as the shales above are well exposed. Just above the uppermost limestone, a few feet of blank section covered over with shale débris, intervenes, beyond which occurs a laminated shale, somewhat blackish

[11] The shales coming in immediately above the Rhotas limestone in this area are probably Bijagarh shales, as already indicated.

[12] One is here reminded of the circumstance that south of Saranga, near Mirgaoti, we find a limestone passing down through a white earthy rock into a porcellanic shaly rock.

in colour in places, and very slightly, if at all, siliceous. This shale is succeeded by some more shales which are earthy and somewhat porcellanic. Over these comes in the thick-bedded sandstone. The dip of the limestone as well as of the shales above is N. 15° W. at 11°.)

The above sections show conformity, and indicate gradual passage.

In all these instances not only is a perfect conformity observable between the Rhotas limestone and the Kaimur beds, but also a gradual passage indicated from the one into the other.

Conclusions with regard to upper boundary of the Lower Vindhyans.

Thus so far as the materials at hand will enable one to judge, this is what we can conclude with regard to the Kaimur-Rhotas junction in the area under notice—

1. That no dip unconformity is observable along this junction, but on the contrary:—
2. Wherever the section is fairly clear, there exists a complete dip conformity between the Rhotas limestone and the Kaimur rocks.
3. That no physical break in the form of abrupt change in the lithological character of the rocks is to be observed, but, on the other hand, from the few cases where the sections have been found to be tolerably clear, the indications all point in the other direction, namely, that there is a physical continuity in the passage from the Rhotas into the Kaimur beds above.

Lower Kaimur sandstone absent in this area.

In conclusion, it may be observed that if the shales which come in immediately above the Rhotas limestone are the Bijaigarh shales, then the Lower Kaimur sandstone, as well as the Kaimur conglomerate, is absent in this area. How far, however, the absence of the Lower Kaimur sandstone may be accounted for by the supposition that the lower part of the Bijaigarh shales may represent here the Lower Kaimur sandstone, that is, how far the case may here be one of only normal lateral replacement is a matter that can only be decided after more extended observation. The conglomerate, however, though it is absent here, certainly indicates a physical break. The occurrence of the conglomerate, however, above the Bijaigarh shales carries the break to the base of the Upper Kaimur beds, that is, some way up from the Rhotas-Kaimur junction. So the conglomerate as an evidence of a break is not of much account so far as the horizon of the boundary-line as hitherto assigned between the Upper and Lower Vindhyans is concerned, being placed, as it is, some distance above it.

Its absence may be due to normal lateral displacement by Bijaigarh shales.

Upper Kaimur conglomerate proves no break at Rhotas-Kaimur junction.

Note on DR. FRITZ NOETLING'S paper *on the Tertiary system in Burma in the Records of the Geological Survey of India for 1895, Part 2:* by MR. THEOBALD, *late Superintendent, Geological Survey of India.*

Having read with much interest the above paper, there are a few remarks I should like to make, as in one case the author attributes to me, as a "logical outcome" views I never contemplated for a moment, and in another matter it seems desirable to elicit more clearly than at present whether Dr. Noetling's correction of a previous statement of mine, really can claim to be any correction at all.

I make no objection to Dr. Noetling terming the beds previously named by me "*Fossil wood group,*" the Irrawaddi division, although I cannot agree with Dr. Noetling that the name bestowed by me was "by no means appropriate," because Fossil wood was found abundantly in certain post-tertiary beds also. The term proposed by myself emphasized and pointed to the fact that in the beds so called the Fossil wood existed *in situ,* and that they were the original depository of the Fossil wood, which in the newer beds was simply derivative and the result of the re-arrangement of the materials of the Fossil wood group proper.—(p. 76 l. c.). At page 83, Dr. Noetling takes exception to a suggestion of mine that the silica with which the fossil trunks of trees had been mineralized might have been derived from springs discharging into the water, wherein I supposed the trees to have floated prior to their entrenchment. "The logical outcome of this theory is that, wherever a single specimen of a silicified log is found *in situ,* we are bound to suppose that just underneath that very log a spring rose in order to petrify it, and having done its work, disappeared without leaving behind it any other traces of its activity." Now Dr. Noetling is fully justified in calling this absurd, but he is wholly wrong in calling it the "*logical outcome*" of anything I said, wrote or thought in the matter! The silica may or may not have been supplied by springs as I suggested, but all I had in my mind was the precisely analogous case of the flint in chalk which was clearly *nascent* or in solution in the cretaceous sea, and in its gelatinous condition gathered round and mineralized any organic substance lying fortuitously at the bottom, as I supposed the silica to have done in the water wherein the fossil trunks in the 'Fossil wood group' as I termed it, did in the waters wherein they floated—before their ultimate mineralization. At page 84, Dr. Noetling makes an important correction of a statement of mine, where he says that Mr. Theobald's "statement that the silicified wood is never bored by Xylophagus mollusca is *absolutely erroneous.*" Of course I am glad to be corrected in a mistake of this kind, but in this case I am not so sure if Dr. Noetling has corrected me! By referring to my Report (Memoirs, Vol. X, p. 66) it will be seen that the fossil wood to which I refer is that of the "*silicified trunks*" which Dr. Noetling admits are embedded in a freshwater formation (p. 86, l. c.) as instanced by the absence of marine organisms. The question hence arises, does the fossil wood of which Dr. Noetling says he has "repeatedly found large pieces riddled by the borings of these mollusca" refer to the silicified trunks, to which *my statement referred,* from the topmost division of my 'Fossil wood group,' or does it refer to logs of fossil wood from the marine beds of Dr. Noetling's Pegu group, as if so it ceases to be a correction of any statement of mine whatever? I have not myself noticed in Pegu any perforated wood whatever, but that such should occur in beds of the character of the marine beds of the Pegu division of Dr. Noetling is of the highest probability, but as matters stand it seems by no means evident that my assertion touching the silicified trunks of my 'Fossil wood group' has received any real correction from any observation of Dr. Noetling—at least within the area to which my remarks were confined—it being of course quite possible that the homologous beds of the Fossil wood group of Pegu might in Upper Burma be represented by beds of an estuarine character rather than a lacustrine or fluviatile one, in which case Dr. Noetling's observation would be perfectly correct, without implying any correction of my own.

Notes from the Geological Survey of India.

I. Madras.– Mr. Middlemiss reports having met several corundum pits in the Sivamallai district of Coimbatore, and in some of these shallow pits magnetic iron ore also appears, concentrated into lumps among the felspar, forming a rich rock with a specific gravity of 3·95. Magnetic iron ore was found as a schist and standing up as a small hill near Hallagomallai. The same rock was also found forming the Chinnamallai (Sennamallai) hill-range near Peranturei, the strike in the rocks coinciding with the long axis of the range.

Mr. Middlemiss also examined the extensive marble beds near Madukarai, which are regularly banded with the ordinary gneisses of the area, and with which they seem to be in structural connection. The deposit appears on the Coimbatore-Madukarai road near the 6th milestone from the former place; its outcrop is roughly elliptical, the major axis running NE to south-east from the point mentioned to within 1½ miles of Kurichi village. The total length of the outcrop is about 7 miles, and the breadth varies from ¼ mile to 50 or 100 yards. It is thickest on the north-west and north-east sides. The marble is greyish white, dark slate grey and flesh-coloured pink, and forms a very valuable building stone, hitherto but little used locally.

II. Burma.—During the early part of this year Dr. H. Warth examined the so-called Nanyaseik ruby tract in the Mogoung district; the area selected by the Burma Government and proclaimed a gem tract is about 80 square miles, although Dr. Warth estimates the actual area over which gems are found in the alluvial deposits as about 10 square miles only. His report will be published hereafter, but the main facts are the following:—

1. He found, in parts of the district examined, sandstone without fossils, which I believe to be the tertiary sandstone with coal seams mentioned by Dr. Noetling (Records Vol. XXVI, Pt. 1, p. 28).

2. A series of acid igneous rocks, most interesting lithologically.

3. Granitic rocks which inclose beds of metamorphic (crystalline) limestone; the latter is of importance, as it is the original matrix of the gems. Dr. Warth is of opinion that this limestone is the same and contains the same minerals as the coarsely crystalline limestone found at the Mogok and Sagyin ruby mines in Burma.

Good rubies and well-coloured spinels with some saphires have been found in the alluvial deposits of the "Nanyaseik gem tract."

III. Baluchistan.—Sub-Assistant Hira Lall surveyed geologically part of the Mari and Bugti hills east of Sibi, and has furnished a report, which will eventually be incorporated in the final Report on the Geology of Baluchistán; it is of interest to note that the great flexures into which the rocks of Baluchistán have been laid are continued into these hills; the sections seen are much the same as already reported on from the country further west and north-west (Records, Vol. XXV, Pt. 1, p. 18), and most of the beds from the massive jurassic limestone to the upper Siwalik conglomerates have been recognized.

CALCUTTA;
The 1st November 1895.

C. L. GRIESBACH, *Director,*
Geological Survey of India.

DONATIONS TO THE MUSEUM.

FROM 1ST NOVEMBER 1894 TO 31ST JANUARY 1895.

Seven specimens of ozokerite, from Boryslaw, Galicia; 1 of slickenside in conglomerate (magura sandstein), from Czarnoozeki near Krosno, Galicia; 1 of Oil-bearing sandstone, from old shaft, Ober Hieroglyphen, Schiefer, Bobrka Oil-field near Krosno, Galicia; 1 of Diorite with iron pyrites, from Bussein bridge, between Somirx and Dissentis, Vorder Rhine; 1 Faceted pebble from the Boulder Bed of Mount Chel Salt Range, Punjab; 2 Striated pebbles from Ramsay's "Glacial breccia," Abberley; 3 Limestone pebbles, pitted, crushed and scratched by earth movements, from the Nagel fluh of the Molasse, St. Gallen, Switzerland; 3 quartzite pebbles facetted by natural sand blast, Copitz, near Dresden.

PRESENTED BY R. D. OLDHAM, A.R.S.M., F.G.S.,
SUPERINTENDENT, GEOLOGICAL SURVEY OF INDIA.

Octahedral crystals of magnetite, from Shamsunderpúr, Bankúra District.

PRESENTED BY N. BELLETTY.

Specimens of mica from the Dhatu Mines, Pananoa hill, 5 miles S. W. of Nawadih, E. I. R.

PRESENTED BY J. D. JONES.

ADDITIONS TO THE LIBRARY.

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Titles of Books. *Donors.*

BRONN, *Dr. H. G.*—Klassen und Ordnungen des Thier-Reichs. Band II, Abth. 3, lief. 17-18; and IV, lief. 36-37. 8° Leipzig, 1894.

LEYMERIE, *A.*—Description Geologique et Palæontologique des Pyrénées et de la Haute-Garonne. With Map and Atlas. 8° Toulouse, 1881.

PERIODICALS, SERIALS, ETC.

American Geologist. Vol. XIV, No. 2. 8° Minneapolis, 1894.

American Journal of Science. Vol. XLVIII, Nos. 285-288. 8° New Haven, 1894.

American Naturalist. Vol. XXIII, No. 273; XXV, Nos. 297, 298 and 300; XXVI, No. 302; and XXVIII, Nos. 333-335. 8° Philadelphia, 1894.

Annalen der Physik and Chemie. Neue Folge, Band LIII, heft 3-4. 8° Leipzig, 1894.

Annals and Magazine of Natural History. 6th series, Vol. XIV, Nos. 82-83. 8° London, 1894.

Athenæum. Nos. 3490-3501. 4° London, 1894.

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Beiblätter zu den Annalen der Physik und Chemie. Band XVIII, Nos. 9-10. 8° Leipzig, 1894.

Chemical News. Vol. LXX, Nos. 1816-1827. 8° London, 1894.

Colliery Guardian. Vol. LXVIII, Nos. 1759-1770, Fol. London, 1894.

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Industries and Iron. Vol. XVII, Nos. 1131-1142. 4° London, 1894.

London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. 5th series, Vol. XXXVIII, Nos. 233-234. 8° London, 1894.

Mining Journal. Vol. LXIV, Nos. 3081-3092. Fol. London, 1894.

Natural Science. Vol. V, No. 30. 8° London and New York, 1894,

Nature Vol. L, No. 1298 to Vol. LI, No. 1309. 4° London, 1894.

Neues Jahrbuch für Mineralogie, Geologie und Palæontologie Band II, heft 3; and Beilage—Band IX, heft. 2. 8° Stuttgart, 1894.

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THE EDITOR.

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THE EDITOR.

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Zeitschrift für praktische geologie. Jahrgang 1894, heft 9-11. 8° Berlin, 1894.

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INDIA.—Annual Statement of the Trade and Navigation of British India with Foreign Countries and of the Coasting trade of the several Presidencies and Provinces in the year ending 31st March 1894. Vols. I and II, No. 28. 4° Calcutta, 1894. GOVERNMENT OF INDIA.

" History of Services of Officers holding gazetted appointments in the Home, Foreign, Revenue and Agricultural, and Legislative Departments, corrected to 1st July 1894. 8° Calcutta, 1894.
GOVERNMENT OF INDIA.

" Monthly Weather Review, June to August 1894. 4° Calcutta, 1894.
METEOROLOGICAL REPORTER TO GOVERNMENT OF INDIA.

" Register of original observations, reduced and corrected, June to August 1894. 4° Calcutta, 1894.
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" Report on the administration of the Meteorological Department of the Government of India, in 1893-94. 4° Calcutta, 1894.
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" Selections from the Records of the Government of India, Foreign Department. Nos. 312—313. Flsc. Calcutta, 1894. FOREIGN DEPARTMENT.

PUNJAB.—Gazetteer of the Lahore District, 1893-94. 8° Lahore, 1894.
PUNJAB GOVERNMENT.

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A specimen of concretionary clay, from Katni, Jabalpur District; and decomposed felspathic breccia cemented with calcite, from Moosrakand, Raniganj.

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